

# Appendix I

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Stream, swamp and groundwater assessment



ROADS AND MARITIME SERVICES  
**M1 PRINCES MOTORWAY**  
**STREAM, SWAMP AND GROUNDWATER**  
**ASSESSMENT**  
Bellambi, NSW

RMS1 – R1A

19 July, 2016

RMS1 - R1A (19 July, 2016)

Roads and Maritime Services  
90 Crown Street  
Wollongong NSW 2500

Attention: Julian Watson

Julian,

**RE: M1 Princes Motorway Stream, Swamp and Groundwater Assessment**

Please find enclosed a copy of the above mentioned report.

Yours Faithfully

**GeoTerra Pty Ltd**

A handwritten signature in black ink, appearing to read 'A. Dawkins', is written over a light grey rectangular background.

**Andrew Dawkins**

Principal (MAusIMM CP-Env)

Distribution: Original

1 electronic PDF copy


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RMS

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Date	Rev	Comments
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## **EXECUTIVE SUMMARY**

The RMS proposes to conduct road re-alignment works between Bulli Tops and Picton Road on the M1 Motorway, near Wollongong in NSW.

The proposal is subdivided into Stage 1 and Stage 2 works areas.

Stage 1 is focussed in an area also known as “Brokers Nose”, which contains historic underground coal mining and associated surface subsidence effects within the Wollongong Coal Limited (WCL) “Russell Vale” mine lease area, which has been mined up to three times.

The Stage 1 and Stage 2 works areas are contained within the Cataract, Bellambi and Allen Creek catchments, which all drain into Cataract Reservoir in the west.

In addition, numerous upland headwater swamps are located in the vicinity of, and within, the proposed Stage 1 works area.

A significant amount of stream, swamp and groundwater studies have previously been conducted in the Stage 1 (Brokers Nose) (a.k.a. Wonga East) area by WCL, which, in addition to the drilling by RMS of two shallow bores (with 1 open standpipe piezometer) and installation of 6 swamp piezometers in the Stage 1 works area, have been used to assess the current environmental status and potential effects from the proposed road works.

The proposal entails the excavation of up to 10.5m of sandstone basement and re-routing the current M1 to reduce the curvature of selected bends.

Drilling by WCL and RMS established the Hawkesbury Sandstone has upper perched, ephemeral aquifers at around 6 - 8mbgl, along with a deeper regional aquifer between 13 - 15mbgl, which is below the proposed road excavation depth.

In association with the re-routing, it is also proposed to excavate out the 0.7ha, dry swamp Ccus17, and to cover over the northern and central western portion, whilst excavating into the southern portion for a total of 0.38ha (or approximately 8%) of Swamp Ccus1, which is dry in the upper and mid reach and saturated in the lower reach, and extends up to 1.27m below surface.

As a result, the proposal will excavate into the upper perched aquifers where the road works cut down approximately 6m or deeper, but the works will not cut into the deeper, perennial, regional aquifer.

The proposed works will affect the water holding and drainage capacity of the lower western edge of Ccus1, of which 0.38ha is proposed to covered over, although will not have as significant an effect on the water holding and seepage capacity of Ccus17, as it is essentially a dry swamp with limited periods of saturation after significant and prolonged rainfall.

There are no anticipated effects on adjoin swamps to the east or downgradient of the proposed works area (outside of Ccus1) or to the west of the existing motorway.

The proposal is not anticipated to have any significant effect on local stream flow or water quality.

Perched, ephemeral, shallow groundwater within the upper Hawkesbury Sandstone will undergo a reduction in both water level and seepage longevity from isolated bedding plane / joint / fracture based seeps that lie above the regional Hawkesbury Sandstone aquifer as a result of the up to 10.5m deep excavation near the Brokers Nose area ridgeline.

However, as the ephemeral, perched seeps desiccate after extended dry periods, the effect on the mostly disconnected, shallow aquifers will be minor.

Enhanced leakage from the perched aquifers into the excavated sections will occur, however, the subsequent seepage rate into local streams should essentially be unaffected, unless significant evaporation off the road surface and associated rock face drainage system occurs, whilst recharge into the underlying regional aquifer will be reduced for the perched aquifers excavated by the works.

The proposed works are not anticipated to have a significant overall effect on recharge to the underlying regional aquifer, stream baseflow or stream water quality where the shallow, ephemeral aquifers seep into local catchments.

## 1. INTRODUCTION

The NSW Department of Transport - Roads and Maritime Services (RMS) propose to re-align sections of the existing M1 Princes Motorway (M1) between Bulli Tops and Picton Road, in an area approximately 4.5km inland from Bellambi, as shown in **Figure 1**.

The proposed M1 re-alignment works will entail excavation into the Hawkesbury Sandstone and associated shallow, colluvial soils, as well as part of two upland swamps, to a maximum cut depth of 10.5m and width of up to 85m.

This document outlines a baseline surface water, swamp and groundwater assessment, principally of the “Stage 1” works area, which is focused on the “Brokers Nose” region within the Cataract Creek and Bellambi Creek catchments, as well as an assessment of the potential impacts of the overall proposal.

The Stage 1 Study Area is defined as the stream, swamp and groundwater catchments that lie upgradient, over and immediately downgradient of the proposed re-alignment section. It is located within land owned by Water NSW, which contains a section of the Metropolitan Special Area headwater catchments in the west, as well as land owned by Wollongong Coal Limited (WCL) in the east of the Study Area. It is also located within the WCL Russell Vale Colliery Consolidated Coal Lease 745 and Mining Lease 1575.

The Stage 1 Study Area and monitoring sites are shown in **Figure 1**.

The Study Area has been subject to historic underground coal mining within the WCL “Russell Vale East” mining domain, where both bord and pillar along with pillar extraction of the Bulli Seam, as well as longwall extraction of the Balgownie Seam has been conducted. Limited secondary longwall extraction of the Wongawilli Seam has been conducted to the west of the current M1, with first working access drives located under the current and proposed M1 as shown in **Figure 2**.

The Stage 1 Study Area contains headwater swamps as well as 1<sup>st</sup> and 2<sup>nd</sup> order tributary creeks that drain into the 3<sup>rd</sup>, and subsequently the 4<sup>th</sup> order catchment of Cataract Creek, and the 3<sup>rd</sup> order channel of Bellambi Creek. It contains headwater reaches of steep gradient valleys that drain off the western slopes of the Illawarra Escarpment into Cataract Reservoir, predominantly within the Cataract Creek catchment, and to a lesser degree, Bellambi Creek catchment.

The Stage 1 Study Area catchments drain directly into Cataract Reservoir and subsequently, to Broughton’s Pass Weir.

Six upland headwater swamps that meet the definition of a Coastal Upland Swamp Endangered Ecological Community (Biosis, 2014) are located in close proximity to the proposed Stage 1 re-alignment works.

Land use in the Stage 1 area consists of undeveloped bushland, the existing M1 motorway, the Brokers Nose fire access track, a power transmission substation and electricity transmission line easements.

Desktop assessments, field monitoring and laboratory analysis have been used to prepare a baseline and potential impact assessment of the shallow groundwater systems, perched upland swamps and streams.



**Figure 1**      **Proposed and Existing M1 Roadways**



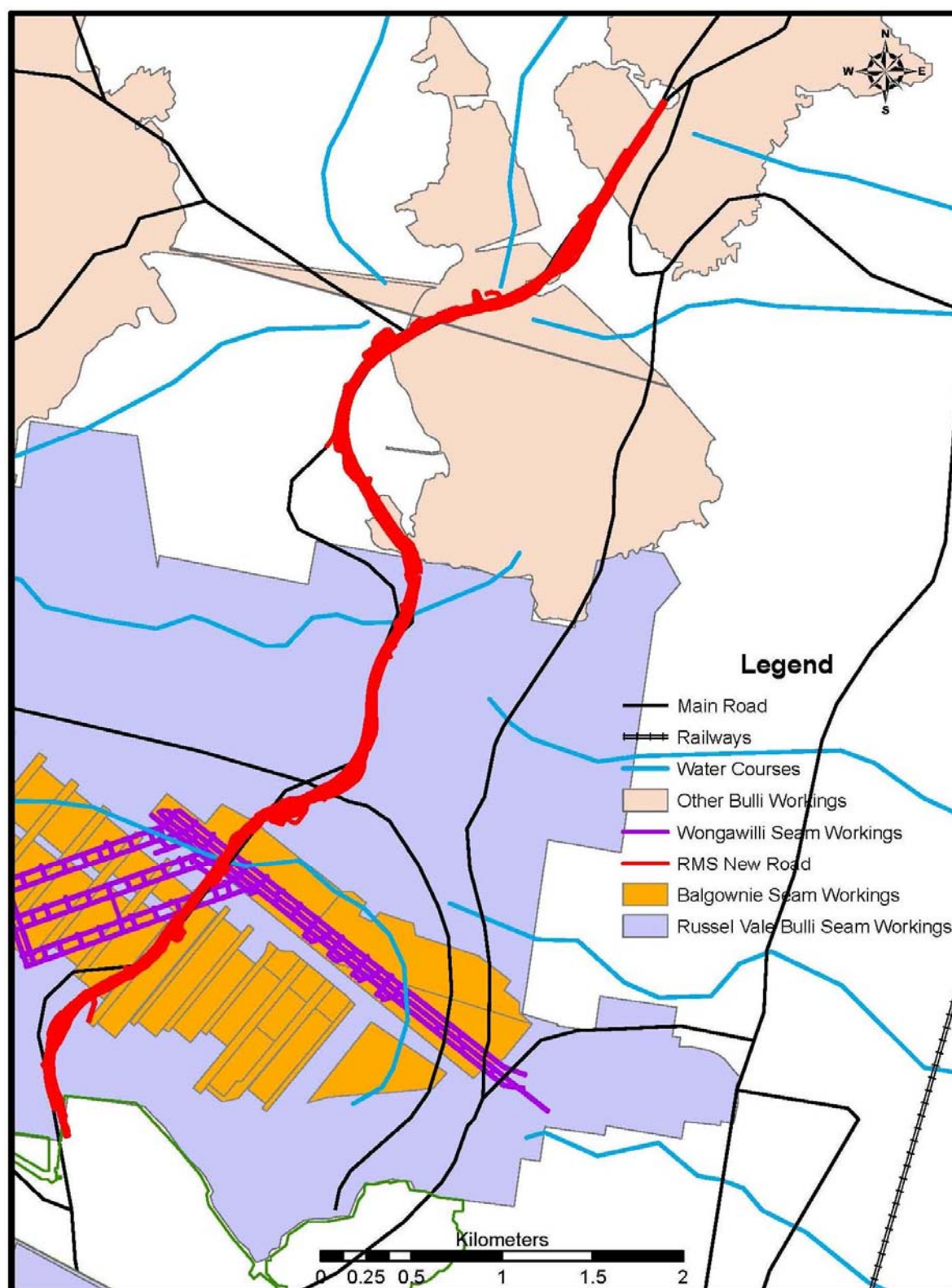


Figure 2 Historic Mining Areas and Roads

Water related features in the Study Area include:

- “losing” streams in the headwaters of the catchment, where stream/ swamp water permeates into the underlying Hawkesbury Sandstone aquifer, and “gaining” streams in the main valleys reaches;
- headwater swamps within the Cataract Creek catchment that contain shallow (<0.9m deep) perched, ephemeral, highly variable water levels;
- shallow, perched, ephemeral aquifers within the upper (<20m deep) Hawkesbury Sandstone;
- a regional groundwater water table which has been intersected between 13m to 48m below surface within the Hawkesbury Sandstone. Where paired measurements are available, the regional aquifer has been shown to be hydraulically separated from the upland swamps by unsaturated, weathered Hawkesbury Sandstone;

### 1.1 Scope of Work

This document addresses the relevant NSW based requirements for the proposal. The investigation was conducted to assess:

- the current standing water levels and water quality within the upland swamps and shallow Hawkesbury Sandstone;
- any observed or inferred groundwater discharge zones into local streams and the presence of any groundwater dependent ecosystems (other than upland swamps);
- the baseline status and potential impacts from the proposal on the local streams, swamps and groundwater systems;
- measures to avoid, mitigate and/or remediate potential impacts on the swamp, stream and groundwater resources, and;
- groundwater, swamp and stream monitoring procedures that will measure any impacts on the systems.

## 2. RELEVANT LEGISLATION AND GUIDELINES

The report has been prepared with reference to the following documents;

- National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC);
- NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation [DLWC]);
- NSW State Groundwater Quality Protection Policy (DLWC);
- NSW Draft State Groundwater Quantity Management Policy (DLWC);
- NSW Groundwater Dependent Ecosystem Policy (DLWC);
- Water Management Act 2000;
- Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011 (NSW Office of Water – NOW); and
- NSW Aquifer Interference Policy (NOW).

## 2.1 State Groundwater Policies and Management Plans

Management of the area's aquifers is covered by the generic State Groundwater Policy (DLWC, 1997) and the Groundwater Quality Protection Policy (DLWC, 1998).

The Study Area lies within Groundwater Flow System 5 (GFS5) Hawkesbury Sandstone - South-East (Grey and Ross, 2003) which includes the catchment of Cataract Dam. As the area is within the Sydney Catchment Authority controlled Metropolitan Special Area, no groundwater supply work development is permitted as it is a protected area.

GFS5 has a sustainable yield estimate of 58,000 ML/year (Grey and Ross, 2003).

The *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* encompasses the Study Area which is within the Sydney Basin Nepean Groundwater Source Area.

The water sharing plan annual rainfall recharge in the Sydney Basin Nepean Groundwater Source Area is assessed at 224,483ML/year. This volume is subdivided into consumptive pool water and environmental water, with 124,915ML/year of the long term annual average recharge being reserved as environmental water. The remaining volume is classified as a sustainable yield or long term average extraction limit of 99,568ML/year.

The current extraction limits and groundwater entitlement volumes do not include all water taken through aquifer interference activities, such as mine voids (remnant or otherwise).

Reservation of environmental water aims to support the long term viability of the aquifers and their dependent ecosystems.

While it does not extend into the Study Area, there is currently an embargo on further applications for sub-surface water licences in the Southern Coalfield (ordered under section 113A of the Water Act, 1912), for areas covering the:

- Nepean Sandstone Water Shortage Zone GWMA 607 (gazetted 8 June 2007); and
- NSW Southern Highlands (gazetted 21 May 2004 and 16 December 2005).

## 2.2 Water Management Act 2000

The *Water Management Act 2000* allows for the development of water sharing plans (WSPs). The rules of WSPs determine how water is to be allocated between water users and the environment. WSPs include extraction limits to ensure that there is sufficient water in the water source to maintain environmental health.

In regard to swamps, the Water Management Act provides for protection of groundwater dependent ecosystems (GDEs) in Sections 3, 5 and 9. GDEs are also protected through clauses 8(1) and 9 as well as Schedule 4 of the WSP.

Upland Swamps within the Study Area are not representative of the Temperate Highland Peat Swamps on Sandstone (THPSS) EEC listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The listing advice for the THPSS EEC (TSSC 2005) contains a number of criteria not met by the upland swamps within the Study Area.

It is understood that the Office of Environment and Heritage (OEH) are currently reviewing the listing of upland swamps, and that the new listing advice is likely to cover swamps on the Woronora plateau.

Notwithstanding, the upland swamps within the Woronara Plateau were considered to be significant by the OEH.

### **2.3 Water Sharing Plan for the Greater Metropolitan Region Groundwater Water Sources 2011**

The water sharing plan also includes rules aimed at protecting Groundwater Dependent Ecosystems consistent with the Groundwater Dependent Ecosystem Policy (DLWC, 2002).

The policy includes wetlands, terrestrial vegetation and caves or karst systems. In the proposed plan, terrestrial ecosystems are protected by a 200m stand off for new bores from any sandstone escarpment where hanging swamps or base flow to rivers is supported by groundwater. It should be noted, however, that no extraction bores are proposed and there are no “hanging” swamps, as opposed to “upland” swamps in the Study Area

The Proposal works area is located within the Sydney Basin Nepean Groundwater Source (Management Zone 2) under the WSP. The rules of the WSP that may be relevant to the proposal include:

- A commercial access licence under a controlled allocation order may be made in relation to any unassigned water in this water source

#### **To minimise interference between neighbouring works**

Clause 39 of the WSP states that no water supply works (bores) to be granted or amended within the following distances of existing bores:

- 400m from an aquifer access licence bore on another landholding, or
- 100m from a basic landholder rights bore on another landholding, or
- 50m from a property boundary (unless written consent from neighbour), or
- 1,000m from a local or major water utility bore, or
- 200m from a NSW Office of Water monitoring bore (unless written consent from NSW Office of Water).

#### **To protect water quality**

Pursuant to clause 40 of the WSP, to minimise the impact on water quality from saline interception in the shale aquifers overlying Sydney basin sandstone, the bore being used to take groundwater must be constructed with pressure cement to seal off the shale aquifer as specified by the Minister.

#### **To protect bores located near sensitive environmental areas**

Clause 41 of the WSP provides that no water supply works (bores) to be granted or amended within the following distances of high priority Groundwater Dependent Ecosystems (GDEs) (non Karst) as identified within the plan:

- 100m for bores used solely for extracting water under basic landholder rights, or
- 200m for bores used for all other access licences.

The above distance restrictions for the location of works from high priority GDEs do not apply where the GDE is a high priority endangered ecological vegetation community and the work is constructed and maintained using an impermeable pressure cement plug from the surface of the land to a minimum depth of 30m.

The Proposal area is not located near any high priority GDEs listed under the WSP.



No water supply works (bores) are to be granted or amended within the following distances from these identified features:

- 500m of high priority karst environment GDEs, or
- a distance greater than 500m of a high priority karst environment GDE if the Minister is satisfied that the work is likely to cause drawdown at the perimeter of the high priority karst GDE, or
- 40m of a river or stream or lagoon (3<sup>rd</sup> order or above),
- 40m of a 1<sup>st</sup> or 2<sup>nd</sup> order stream, unless drilled into underlying parent material and slotted intervals commence deeper than 30m. (30m may be amended if demonstrate minimal impact on base flows in the stream.), or;
- 100m from the top of an escarpment.

#### **To manage the use of bores within restricted distances**

Under clause 44 of the WSP, the maximum amount of water that can be taken in any one year from an existing work within the restricted distances to minimise interference between works, protect sensitive environmental areas and groundwater dependant culturally significant sites is equal to the sum of the share component of the access licence nominating that work at commencement of the plan.

## **2.4 NSW Aquifer Interference Policy**

The NSW Aquifer Interference Policy was released in September 2012.

Under the policy, and the associated WM Act, an aquifer is a geological structure or formation that is permeated with water or is capable of being permeated with water. Groundwater is defined as all water that occurs beneath the ground surface in the saturated zone. For the purpose of the policy, the term “aquifer” has the same meaning as groundwater system.

The *Water Management Act 2000* defines an aquifer interference activity as the:

- penetration of an aquifer,
- interference with water in an aquifer,
- obstruction of the flow of water in an aquifer,
- taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations, and the;
- disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

A water license is required under the *Water Management Act 2000*, unless an exemption applies or water is being taken under a basic landholder right, where any act by a person carrying out an aquifer interference activity causes the:

- removal of water from a water source;
- movement of water from one part of an aquifer to another part of an aquifer;
- movement of water from one water source to another water source, such as from an aquifer to an adjacent aquifer, an aquifer to a river/lake, or from a river/lake to an aquifer.

The AIP lists a number of activities that are deemed to be minimal impact aquifer interference activities. In terms of the proposal, activities considered as having a minimal impact include:

- sampling and coring using hand held equipment;
- trenching and costeaning;
- access tracks;
- leachate ponds and sumps if constructed, operated and abandoned in accordance with appropriate standards and guidelines as determined by the Minister;
- caverns, tunnels, cuttings, trenches and pipelines (intersecting the water table) if a water access license is not required;

The Aquifer Interference Policy also states that monitoring bores are deemed to be minimal impact activities if the bores are:

- required by a development consent under Part 4 or an approval under Part 5.1, of the Environmental Planning and Assessment Act 1979,
- required or undertaken as a result of an environmental assessment under Part 5 of that Act,
- required by a condition of an environment protection license under the Protection of the Environment Operations Act 1997, or where;
- core holes, stratigraphic (chip) holes, geo-environmental and geotechnical bores, works or activities intersecting the water table if they are decommissioned in such a way as to restore aquifer isolation to that which existed prior to the construction of the bore, work or activity and that the decommissioning is conducted within a period of 28 days following completion of the bore, work or activity;

The *Water Management Act 2000* includes the concept of ensuring "no more than minimal harm" for both the granting of water access licenses and the granting of approvals. Water access licenses are not to be granted unless the Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source as a consequence of water being taken under the license.

Where a water access license has been applied for by a method consistent with a controlled allocation process then adequate arrangements are in force to ensure that no more than minimal harm will occur. This is because the controlled allocation process allows for the allocation of a proportion of the unassigned water within the relevant water source using a conservative approach. Furthermore, unassigned water can only occur where total water requirements within a water source are less than the long-term average annual extraction limit specified in the relevant water sharing plan.

Where water is to be taken from a water source that has no unassigned water or insufficient unassigned water to account for any inflows to the activity, either surface or groundwater, then water entitlements will need to be purchased from an existing licensed user.

Any access license dealing requiring the Minister's consent will need to consider the requirements of section 71Y of the *Water Management Act 2000*, including the water management principles that require water sources to be protected and social and economic benefits to be maximised.

Aquifer interference activities may induce flow from adjacent groundwater sources or flow from connected surface water sources to compensate for the water taken from the aquifer in which the activity is occurring or to fill the void created in the aquifer.

Where an aquifer interference activity is taking water from a groundwater source, and this causes movement from an adjacent, overlying or underlying groundwater source, separate aquifer access licenses are required for the groundwater source and for any adjacent, overlying or underlying groundwater sources.

Where an aquifer interference activity causes movement of water from a connected regulated or unregulated river water source into the groundwater source, then an access license in the regulated or unregulated river water source is required to account for the take of water from that water source and another access license in the groundwater source is required for the remainder of the take.

Where an aquifer interference activity is incidentally taking water from a river it must be returned to that river when river flows are at levels below which water users are not permitted to pump.

It is the proponent's responsibility to ensure that the necessary licenses are held with sufficient share component and water allocation to account for all water take, both for the life of the activity and after the activity has ceased.

In determining what licenses are required and which water source(s) the activity will take water from, the following need to be considered;

- prediction of the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity and after closure of the activity. Where required, predictions should be based on modeling conducted in accordance with the Australian Groundwater Modeling Guidelines;
- how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources;
- how any relevant license exemptions might relate to the water to be taken by the activity;
- whether the water is taken at a fixed or varying rate;
- whether sufficient entitlements and allocations are able to be obtained;
- consideration of water sharing plan rules;
- by what mechanism and license category the water will be obtained, consistent with any trading rules specified in either the Minister's access license dealing principles and/or relevant water sharing plans;
- the effect that activation of existing entitlement may have on future available water determinations for the proposed license category and entitlement volume, and;
- a strategy for accounting for any water taken beyond the life of the operation of the project, such as holding the appropriate entitlement or surrendering a component of the entitlement at the end of the project. Where a license or part of a license has been surrendered to the Minister, a security deposit or condition of consent under the EP&A Act may account for or require the upfront payment of fees and subsequently the license may be retained for the period of ongoing take of water or cancelled.

Where uncertainty in the predicted inflows may have a significant impact on the environment or other authorised water users, the applicant will need to report on:

- potential for causing or enhancing hydraulic connection between aquifers or between groundwater and surface water sources, and quantification of this risk;
- quantification of any other uncertainties in the groundwater or surface water impact modeling conducted for the activity; and
- strategies for monitoring actual and reassessing any predicted take and how

changes will be accounted for, including analysis of water market depth and/or in situ mitigation and remediation options

Where there is ongoing take of water, the holder must retain a license until the system returns to equilibrium or surrender it to the Minister. Surrendering entitlements that adequately cover any likely future low available water determination periods is preferable.

The NSW Office of Water will assess the potential impacts of the aquifer interference activity against the minimal impact considerations, as well as any specific rules in a relevant water sharing plan

There are two levels of minimal impact considerations specified in **Table 1**.

Groundwater sources have been divided into "highly productive" and "less productive". Highly productive groundwater is defined as a source that is declared in the Regulations and:

- have total dissolved solids less than 1,500 mg/L, and;
- contain water supply works that can yield water at a rate greater than 5 L/sec.

Highly productive groundwater sources are grouped into:

- Alluvial;
- Coastal sands;
- Porous rock;
  - Great Artesian Basin - Eastern Recharge and Southern Recharge;
  - Great Artesian Basin - Surat, Warrego and Central;
- other porous rock, and
- fractured rock

Less productive groundwater sources are grouped as:

- Alluvial;
- Porous rock, and;
- Fractured rock.

The Proposal is within a Less Productive Porous Rock groundwater source area.

**Table 1 Minimal Impact Considerations for Aquifer Interference Activities – Less Productive Porous Rock Groundwater Sources**

Water Table	Water Pressure	Water Quality
<b>LEVEL 1</b>		
<p>Less than or equal to 10% cumulative variation in the water table, allowing for typical post water sharing plan (WSP) variations, 40m from any:</p> <p>High priority groundwater dependent ecosystems, or</p> <p>High priority culturally significant site;</p> <p>listed in the schedule of the relevant WSP.</p> <p>A maximum of 2m decline cumulatively at any water supply work.</p>	<p>A cumulative pressure head decline of not more than 2m decline at any water supply work.</p>	<p>Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.</p>
<b>LEVEL 2</b>		
<p>If there is more than 10% cumulative variation in the water table, then appropriate studies will need demonstrate to the ministers satisfaction that the variation will not prevent the long term viability of the dependent ecosystem or significant site</p> <p>If more than 2m decline cumulatively at any water supply work then make good provisions should apply.</p>	<p>If there is more than a 2m pressure head decline, then appropriate studies will need to demonstrate to the ministers satisfaction that the decline will not prevent the long term viability of the water supply works unless make good provisions apply</p>	<p>If the above condition is not met, then appropriate studies will need to demonstrate to the minister's satisfaction that the change in groundwater quality will not prevent the long term viability of the dependent ecosystem, significant site or affected water supply works.</p>

If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable.

Where an activity's predicted impacts are greater than Level 1, but they exceed it by no more than the accuracy of a robust model, then the project will be considered as having acceptable impacts, with monitoring, as well as potential mitigation or remediation required during operation.

If the predicted impacts exceed Level 1 by more than the accuracy of a robust model, then the assessment will need to involve additional studies, and if the impacts will not prevent the long-term viability of the water dependent asset, then the impacts will be considered acceptable.

A risk management approach to assessing the potential impacts of aquifer interference activities will be adopted, where the level of detail required is proportional to the likelihood of impacts occurring on water sources, users and dependent ecosystems and the potential consequences.

In addition to the volumetric water licensing considerations, a proponent will need to provide;

- baseline groundwater depth, quality and flow;
- a strategy for complying with any water access rules;
- potential water level, quality or pressure impacts on nearby water users, connected ground / surface water sources and groundwater dependent ecosystems;
- the potential for increased saline or contaminated water inflows to aquifers and highly connected river systems;
- the potential to cause or enhance hydraulic connection between aquifers;
- the potential for river bank instability, or high wall instability or failure to occur;
- the method for disposing of extracted water;
- contingency plans or remedial measures if impacts are outside of the licensing and approval requirements.

#### Aquifer Interference Approval

Under the WM Act, an aquifer interference activity requires:

- the necessary volumetric WALs, and a;
- separate aquifer interference approval.

An aquifer interference approval confers a right on its holder to carry out specified aquifer interference activities at a specified location or area.

Under section 91F of the WM Act, it is an offence to carry out an aquifer interference activity without an aquifer interference approval. An aquifer interference activity includes the penetration, interference or obstruction of flows within an aquifer or to take or dispose of waters from an aquifer.

However, section 91F of the WM Act does not currently apply. Section 88A provides that Part 3 of Chapter 3 (including section 91F) applies to each part of the State or each water source and each type or kind of approval that relates to that part of the State or that water source that is declared by proclamation. In essence, the AIP applies, however the approvals framework has not been finalised.

A framework for the implementation of the AIP was produced by NoW (October 2013) and this report addresses the key issues in this document.

#### Stream Baseflow Impact Licensing

Any reduction in stream baseflow as a result of depressurisation will also require a water access licence under the WSP for the unregulated rivers.

The Project is located within the Upper Nepean and Upstream Warragamba water source under the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011*.

## 2.5 Environment Protection and Biodiversity Conservation Act 1999

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is the main Commonwealth environmental legislation that provides legal framework to protect and manage matters of environmental significance including nationally and internationally important flora, fauna, ecological communities and heritage.

Pursuant to the EPBC Act, an action that has, will have, or is likely to have a significant impact upon Matters of National Environmental Significance (MNES) is declared a “controlled action” and requires the approval of the Commonwealth Minister for Environment.

Approval under the Commonwealth EPBC Act is in addition to requirements under NSW State legislation.

The EPBC Act lists Matters of National Environmental Significance (MNES) that must be addressed when assessing the impacts of a proposal. The criteria are presented below for;

### **Hydrological Characteristics, covering changes in the:**

- water quantity, including the timing of variations in water quantity, and;
- area or extent of a water resource.

### **Water Quality, in regard to, if;**

- there is a risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised;
- a project creates risks to human or animal health or to the condition of the natural environment as a result of the change in water quality;
- a project substantially reduces the amount of water available for human consumptive uses or for other uses, including environmental uses, which are dependent on water of the appropriate quality;
- a project could cause persistent organic chemicals, heavy metals, salt or other potentially harmful substances to accumulate in the environment;
- a project could seriously affect the habitat or lifecycle of a native species dependent on a water resource;
- there is a significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives), and if:
- high quality water is released into an ecosystem which is adapted to a lower quality of water

### **3. PREVIOUS STUDIES**

#### **3.1 Streams**

Ongoing monitoring of stream water quality, groundwater seepage and stream flow studies conducted since 2001, up to the completion of the extraction of Longwalls 4, 5 and part of Longwall 6 by Wollongong Coal Ltd (WCL) in the Wongawilli Seam, to the west of the proposal, were assessed by GeoTerra (2014).

Monitoring was conducted by WCL personnel at varying intervals depending on weather, project status and financial inputs.

A local and regional stream assessment was conducted by WRM Water & Environment (2014) (2015).

#### **3.2 Upland Swamps**

The upland swamps in the Study Area have been assessed by Biosis (2015A, B).

#### **3.3 Groundwater**

GeoTerra (2012) and GeoTerra / GES (2014) (2016) conducted groundwater modelling and impact assessment for the proposed Russell Vale East proposed mining domain as part of the WCL Underground Expansion Project Part 3A application.

#### **3.4 Surface Subsidence**

The extent of historic fracturing and overburden depressurisation due to subsidence over previous WCL workings, and assessment of the potential subsidence effects has been assessed by SCT Operations (2014) (2015).



## 4. HISTORIC AND PROPOSED MINING

### 4.1 Historic Mining

Three coal seams have been mined by WCL in the Russell Vale Colliery lease, in the vicinity of the Stage 1 works area, whilst the Excelsior (Bulli Seam) workings are present to the north, underneath the Stage 2 roadworks area.

Within the WCL lease area, the uppermost workings are in the 2.0 - 2.5m thick Bulli Seam, where most of the previous activity has occurred. The 1.3m thick Balgownie Seam is located 5 - 10m below the Bulli Seam, whilst the 7 - 9m thick Wongawilli Seam is located 18 - 26m below the Balgownie Seam, although only the lowermost 3.0 - 3.5m of the Wongawilli Seam has been mined.

#### 4.1.1 Bulli Seam

The Bulli Seam was mined between the late 19th Century and about 1950, initially as a hand worked bord and pillar operation and then with mechanised pillar extraction. Mining continued under and to the west of Cataract Reservoir, initially as continuous miner pillar extraction operations and then as a longwall mining operation until 2002.

#### 4.1.2 Balgownie Seam

The Balgownie Seam was mined in the late 19th Century in the Russell Vale East area using hand worked methods for a brief period. Mining restarted in the late 1960s with continuous miners, then from 1970 to 1982 as one of the first longwall operations in Australia.

To the north, additional mining included first workings continuous miner bord and pillar thin seam mining between 2001 and 2003 in Gibson's Colliery (S Wilson, pers comm.).

#### 4.1.3 Wongawilli Seam

Installation of the Wongawilli Seam mining access started in 2008 at Russell Vale East, to the west of and under the proposed roadworks, with subsequent secondary extraction occurring intermittently to the west of the M1 between April 2012 and July 2015.

**Figure 2** shows the regional historic mining areas and their relationship with the proposed M1 re-alignment.

### 4.2 Proposed Mining

Although WCL are currently in the process of applying for approval of the underground mine expansion at Russell Vale East, none of the current application workings underlie the proposed M1, and there is no indication whether, or not, the WCL proposal will be approved in its current form.

## **5. STUDY AREA DESCRIPTION**

### **5.1 Stream Catchments and Topography**

Stream monitoring in the Russell Vale Colliery lease area has been conducted since November 2010.

The following sections describe individual catchments that are relevant to the proposal.

#### **5.1.1 Cataract Creek**

Cataract Creek is a 4<sup>th</sup> order stream for most of its length and is approximately 5.5km long from its headwaters to the full supply level of Cataract Reservoir.

Channel invert elevations fall from approximately 340m AHD to 285m AHD, with the channel being relatively gently sloping at a gradient of 0.9% for most of its length, except for a 0.5km reach in its headwaters, which slopes at 2.5%.

The proposal contains two road works excavation areas, with one located in the headwaters of the catchment in the vicinity of Brokers Nose, and a second in the headwater and mid slopes near the watershed with Bellambi Creek.

The proposed works do not intersect any defined stream channels at Brokers Nose, and only a single headwater channel of a 1<sup>st</sup> order gully near the watershed with Bellambi Creek.

#### **5.1.2 Bellambi Creek**

Bellambi Creek is a 3<sup>rd</sup> order stream upstream for the first 5.5km, then 4<sup>th</sup> order to the Cataract Reservoir backwater. It is approximately 6.4km long from its headwaters to the full supply level of Cataract Reservoir.

Channel invert elevations fall from approximately 453m AHD to 286m AHD, with the channel being relatively gently sloping at a gradient of 0.6%, except for the first 1km upstream reach, which slopes at around 2.8%.

The M1 overlies the main channel of Bellambi Creek, however, only minor road works are proposed in its catchment.

#### **5.1.3 Allens Creek**

The Stage 2 works area is contained within the headwaters of the northerly draining Allen Creek.

Limited road re-alignment works are proposed in this area.

### **5.2 Climate**

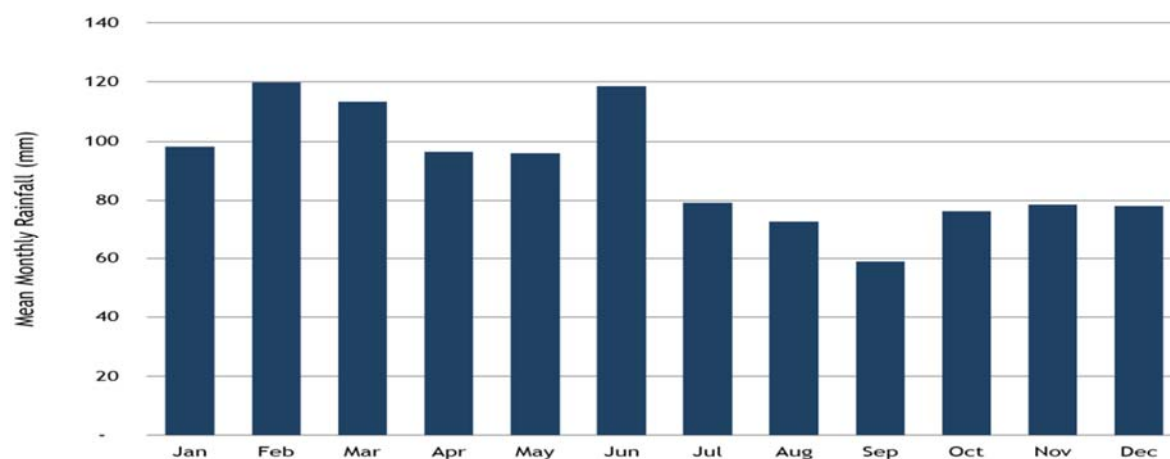
#### **5.2.1 Rainfall**

Daily rainfall has been recorded by the Bureau of Meteorology (BOM), Water-NSW and its predecessors, and the nearest stations with the longest records are located at Cataract and Cataract Dam, with good quality records extending from 1883 to 1966 and 1904 to 2014 respectively.

The BOM's SILO data service has prepared Patched Point Datasets (PPDs) from the Cataract and Cataract Dam records. Gaps in the records are infilled with data interpolated from other nearby stations to provide continuous records between 1889 and the present day (WRM Water and Environment, 2015).

Annual rainfall at Cataract Dam between 1889 and 2013 varied from 480mm in 1944 to 2,293mm in 1950, with a mean annual rainfall of 1,085mm/a.

Cataract Dam rainfall is highest between January and June, and lowest between July and December as shown in **Figure 3**.

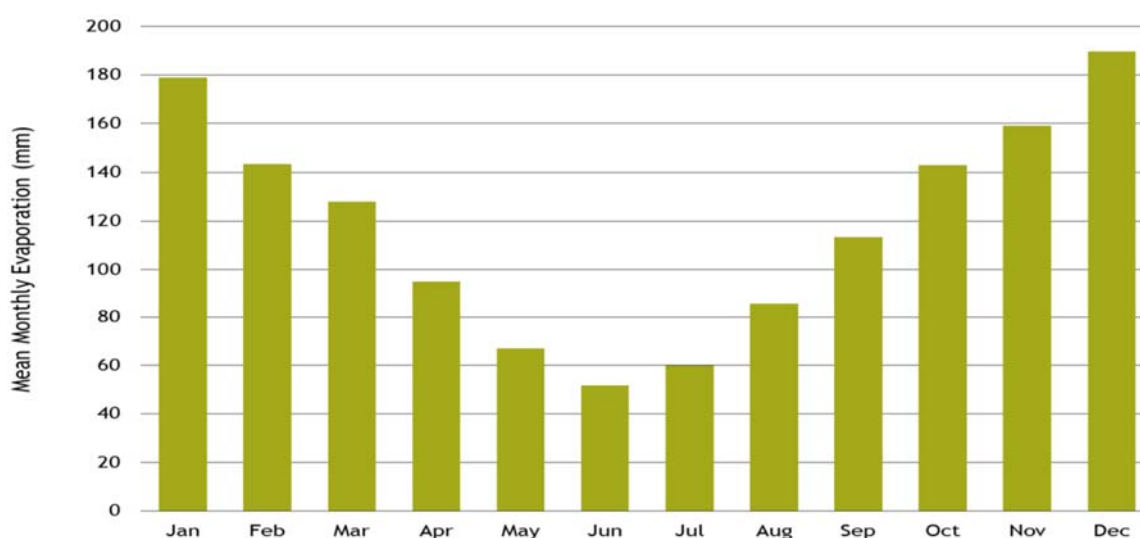


**Figure 3 Variation in Mean Monthly Rainfall at Cataract Dam**

### 5.2.2 Evaporation

The mean annual pan evaporation at Cataract Dam is approximately 1,420mm/yr as shown in the PPD data in **Figure 4**, and is highest in the summer months.

There is no Bureau of Meteorology evaporation data available for this location.



**Figure 4 Monthly Pan Evaporation at Cataract Dam (PPD)**

On the basis that the reservoir has a surface area of 8,500ha, this equates to an average annual evaporation rate (at 1,420mm/yr) of 120,700ML/year off the surface of the reservoir (when it is at Full Supply Level).

### 5.3 Geology

The M1 works area is situated at the southern end of the Permo-Triassic (225-270 million years) Sydney Basin.

The area is predominantly covered by shallow hillslope-based colluvium, with very thin to no alluvial sedimentary deposits in the valley floors.

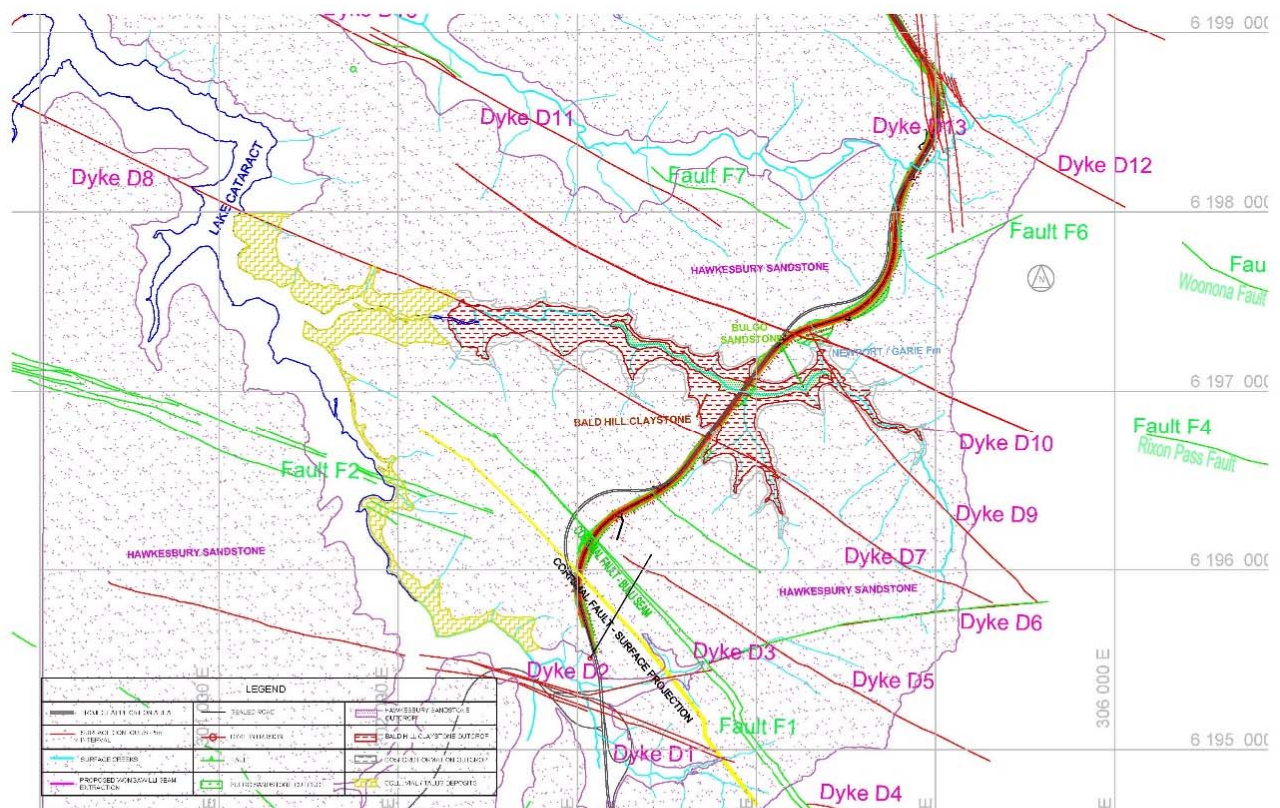
Outside of the upland swamps, there are no alluvial deposits of any significance.

Quaternary unconsolidated alluvial and colluvial sediments are also present within valley fill and headwater upland swamps, and are generally less than 2m thick, comprising humic sands and clayey sands overlying weathered Hawkesbury Sandstone.

The Quaternary sediments are, in turn, sequentially underlain by the Hawkesbury Sandstone, which is a bedded to massive quartzose sandstone with grey shale lenses up to several metres thick is uppermost in the stratigraphic sequence, except where it has been eroded in the headwater valleys of Cataract and Bellambi Creeks.

The Hawkesbury Sandstone can contain up to 4% manganiferous siderite and up to 0.5% of iron sulfide (principally marcasite) with minor solid solution incorporation of nickel, zinc and manganese sulfides in the deeper, unweathered material, beneath the likely depth of the proposal. It outcrops in the catchment headwaters with the underlying Newport and Garie Formations, Bald Hill Claystone and Bulgo Sandstone exposed in the valley floors.

Local and regional surface geology, fault and dyke mapping is shown in **Figure 5**.



**Figure 5 Surface Geology and Structures**

#### 5.4 Basement Hydrogeology

Relevant hydrogeological domains include:

- hydraulically disconnected (perched) upland swamps;
- the hydraulically disconnected (perched), ephemeral, weathered Hawkesbury Sandstone, and;
- the deeper Hawkesbury Sandstone, and the underlying Bulgo Sandstone, Newport and Garie Formations and Bald Hill Claystone.

Due to the steep topography, there is no notable groundwater bearing stream based alluvium within the Study Area.

The main aquifer is the dual porosity (i.e interstitial pore space along with fractures and joint porosity) Hawkesbury Sandstone which, although having generally low permeability, can provide relatively higher groundwater yields compared to deeper lithologies.

Regional water levels within the sandstone result from interaction between rainfall infiltration (recharge) through the shallow weathered zone into the underlying clastic rocks and with topography over geologic time. Rainfall infiltration elevates the water table whilst drainage channels incised through to the water table can provide seepage pathways that constrain groundwater levels to the elevation of stream beds through seepage in “gaining” stream reaches.

Evapo-transpiration losses from deep and shallow rooted vegetation would also reduce the phreatic surface of the water table to varying degrees.

The low groundwater flow rates within the Hawkesbury Sandstone are primarily horizontal with minor vertical leakage due to the dominant horizontal bedding planes and bedding discontinuities interspersed with generally poorly connected vertical joints.

Ephemeral perched water tables within the upper 20m of the Hawkesbury Sandstone that are hydraulically disconnected from the underlying regional aquifer, can occur following extended rainfall recharge periods.

In rainfall recharge periods, water levels in shallow aquifers respond by rising, whilst in dry periods, levels are lowered through seepage to the local watercourses. During dry periods the salinity in surface drainages normally rises as the basement baseflow seepage proportionally increases.

Measured standing water levels in the Hawkesbury Sandstone range from to 6m to 39m below surface.

Water quality in the Hawkesbury Sandstone generally has low salinity (81 - 420 $\mu$ S/cm) with relatively acidic pH (3.22 - 5.45) and can contain high iron levels up to 12.0mg/L.

There are no private bores or wells located within close proximity to the proposed road works.



### 5.5 Stream Flow, Stream Water Quality, Rainfall and Land Use

The Stage 1 road works area stream flow, stream water quality, rainfall and land use is described in detail in WRM Water and Environment (2014) and GeoTerra (2014A), which are summarised below.

Based on drilling information and site observations, the local streams are interpreted to be “losing” in the catchment headwaters and “gaining” in the lower reaches.

Surface water drainage to the streams is through ephemeral first and second order gullies, with the smaller gullies discharging into major streams from elevated stream beds after sufficient rain, whilst the majority of rain infiltrates into the plateau swamps, soil and weathered sandstone.

Recharge to the shallow, and subsequently the deeper regional groundwater system, occurs over an extended delay of months to years. It occurs after meteoric water soaks through the soil and bedrock, with the majority of water discharging back into the creeks from temporary seeps in swamps and creek beds along preferential horizontal flow regimes in the shallow outcropping bedrock.

The predominantly horizontal flow regime and restricted vertical recharge is essentially determined by the:

- horizontally bedded strata with preferential flow along bedded zones with coarser grain size,
- claystone/mudstone banding at the base and tops of sedimentary facies which restrict vertical migration and enhance horizontal flow at the base of the more porous unit,
- fracture zones enhancing horizontal flow through the strata; and
- bedding planes or unconformities located immediately above finer grained sediments or iron rich zones.

Groundwater seepage to streams generally occurs as isolated iron stained seeps, where low volume and variable duration seeps discharge for a few days to weeks after significant rain. The seeps are generally located at the interface between coarser and underlying finer sandstone or shale/ sandstone interfaces, which restrict vertical flow through the bedrock and enhance lateral flow.

Most observed seeps in the local streams are anticipated to flow at less than 1L/sec.

The current interaction between surface water, perched and regional groundwater systems is postulated to be that pre-minë subsidence” conditions prevail, in that during wet periods there is a net contribution of groundwater to the surface system, while in dry conditions there is a net loss of surface water, with the resulting surface flow depending on the relative balance between seepage baseflow and stream outflow.

Mapping of the stream reach over the historic WCL workings indicates that Cataract Creek is an ephemeral, “losing” stream in its first order headwater tributaries to upstream of the current M1, then becomes perennial downstream where a seepage face is present in a 3m high sandstone rock face, down to its junction with Cataract Reservoir.

The surface water and shallow groundwater system is interpreted to be hydraulically isolated from the Bulli Seam workings in areas where only overlapping Bulli and Balgownie secondary extraction is present, although may not be separated where the overlapping

workings of the Wongawilli Seam (Longwalls 4 and 5) have been mined.

At present there are local scale aquifer systems in the Russell Vale Colliery lease area over the subsided zone of the Bulli, Balgownie and Wongawilli Seam workings.

It is assessed an upper fractured unit is present from surface to approximately 20m below ground, which transitions into an elevated horizontal permeability zone caused by vertical bedding dilation, which does not necessarily contain a hydraulically connected, subsidence enhanced, vertical permeability component. This zone subsequently transitions into a sequentially higher permeability zone in the goafed and overlying deeper lithologies which can have a higher potential hydraulic connection to the Wongawilli Seam workings.

The Hawkesbury Sandstone and Bulgo Sandstone groundwater systems are not interpreted to be hydraulically separated in the valley of Cataract Creek where the Bald Hill Claystone is eroded through to the Bulgo Sandstone, downstream of the freeway. In addition, they may not be separated where the sandstone may have locally enhanced permeability due to its lack of lithostatic pressure where it has limited or no overburden, or where the Bald Hill Claystone has been fractured by subsidence.

The creeks and perched swamps are separated from the underlying regional groundwater system by a profile of unsaturated strata.

## **5.6 Groundwater Dependent Ecosystems and Upland Swamps**

The proposed works are located within the Sydney Basin Sedimentary Rock Groundwater System as described in the NSW State Groundwater Dependent Ecosystems Policy (SGDEP) (DLWC, 2002) which has its associated dependent ecosystems.

The SGDEP recognises four groundwater dependent ecosystems types in NSW, namely:

- Terrestrial vegetation;
- Base flows in streams;
- Aquifer and cave ecosystems; and
- Wetlands.

Groundwater dependent ecosystems present in the area are:

- terrestrial vegetation, in terms of headwater upland swamps which are susceptible to changes in groundwater seepage inflow rates, the balance between rainfall and evaporation, the effect of bushfires and changes to the erosional regime; and
- baseflows in streams, which can be affected by changes in groundwater seepage inflow rates to a stream and the balance between rainfall and evaporation.

## 5.7 Upland Swamps

Biosis (2014) indicates that numerous upland headwater swamps that meet the definition of the Coastal Upland Swamp Endangered Ecological Community in the Study Area, although there are no valley fill swamps.

The study highlighted the complexity and variability of the associated vegetation communities, with some swamps having a fully developed, saturated, humic sandy clay matrix up to 1.6m deep within the WCL lease area, through to essentially dry, shallow sandy clay locations with a high degree of shallow or subcropping sandstone and a thin weathered, colluvial, sandy clay soil profile.

The swamps adjacent to, or within, the proposed road works area have a maximum depth of 0.95m and are generally small, dry and without significant humic soil development.

Field mapping, aerial photography and Lidar interpretation indicated that the Study Area swamps are predominantly drier, shallower and less spatially continuous than a “typical” humic, saturated swamp (Biosis, 2014).

The upland headwater swamps have relatively small upstream catchments, with their saturation relying on rainfall recharge directly into the sandy sediments, as well as seepage out of upslope Hawkesbury Sandstone and their degree of organic (humic) content.

The storage and water transmission characteristics of the surrounding and underlying Hawkesbury Sandstone is critical in sustaining these environments.

The swamps occur in either headwater tributary valleys that are characteristically derived from colluvial sand erosion from sandstone dominated ridgelines or along the riparian zone of major creeks. They are only located over Hawkesbury Sandstone which provides a low permeability base on which the swamp sediments and organic matter accumulate.

Regional groundwater flow within the Hawkesbury Sandstone is hydraulically beneath, and separated by between 12 - 15m from the base of the swamps.

Due to their gentle slope, only the larger swamps contain small, shallow, poorly defined open channels, which are generally short and located at the downstream reaches, whilst ephemeral patches of saturated sediment can be present in headwater sections.

The swamps are not located near any cliff scarps, as is the case for “hanging” swamps in the Blue Mountains. As such there are no “hanging” swamps (by definition) in the Study Area.

The headwater swamps are predominantly located within gently sloping, shallow trough shaped gullies, although they can partially extend onto steep slopes, benches or valley sides, where the plateau is not dissected by creek lines.

The central axes of the swamps are generally saturated after substantial recharge events, though the margins can comparatively dry out after extended dry periods.

The sand and humic material increases a swamp’s water holding capacity and subsequently discharges rainfall infiltration, groundwater seeps and low-flow runoff into the local streams. Rainfall saturates the swamp after storms and with a slow, delayed discharge due to the low slopes when the recharge exceeds evaporation.

Sediments below and laterally lensing into the humic material are variable in nature and can be composed of fine to medium grained sands that can contain clayey bands and comprise a grey to mottled red-orange colour due to insitu weathering.



#### 5.7.1 Ccus1

Ccus1 is a relatively larger swamp in the vicinity of, or within, the proposed road works, with an area of approximately 4.81 ha, with the western edge comprised of Tea-Tree Thicket and fringing Eucalypt Woodland.

Approximately 0.38ha, (or approximately 8%) of the western edge of the swamp will be either covered in the northern (downgradient) and central portion, and excavated in the southern (upgradient) portion for the proposed road works.

#### 5.7.2 Ccus15

Ccus15 is a small swamp located downstream of the proposed road works and upstream of the current M1, with an area of approximately 0.06ha.

It is comprised of Tea-Tree Thicket with fringing Eucalypt Woodland.

None of the swamp will be excavated for the proposed road works.

#### 5.7.3 Ccus17

Ccus17 is also a small swamp located within the excavation area of the proposed road works and upstream of the current M1, with an area of approximately 0.07ha.

It is comprised of Tea-Tree Thicket with fringing Eucalypt Woodland.

All of the swamp will be excavated for the proposed road works.

#### 5.7.4 Ccus20

Ccus20 is a smallish swamp located adjacent to, although downslope of, the proposed road works excavation area and is downslope of the current M1, with an area of approximately 0.55ha.

It is comprised of Banksia Thicket with fringing Eucalypt Woodland.

None of the swamp will be excavated for the proposed road works.

Photograph of the swamps are shown below, whilst their locations are shown in **Figure 6**.



**Plate 1: Swamps Adjacent to, or Over the Proposed M1 Roadworks Area**



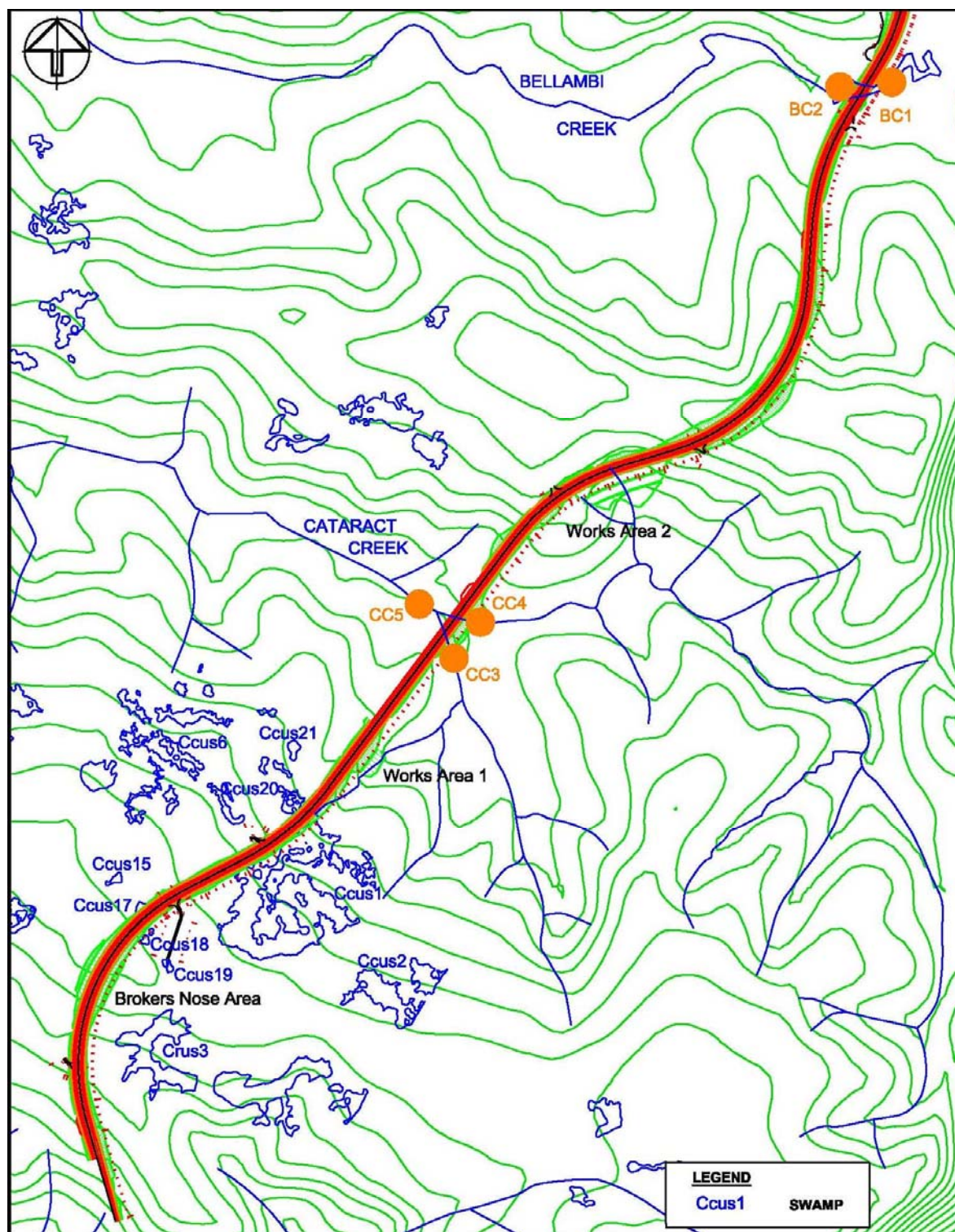


Figure 6 Swamps, Streams and Stream Monitoring Locations

## **6. PREVIOUS STREAM, SWAMP AND GROUNDWATER EFFECTS**

### **6.1 Streams**

To date, no definitive effects have been observed from underground colliery mine subsidence effects on the proposed road works area streams (GeoTerra 2014), however, there is a probable link between the high iron hydroxide levels in Cataract Creek and subsidence, which occurred prior to the time when dedicated stream monitoring commenced.

### **6.2 Swamps**

No definitive effects have been observed from underground colliery mine subsidence effects on the proposed road works area swamps (Biosis 2014A).

### **6.3 Groundwater**

Subsidence of the Hawkesbury Sandstone (and underlying lithologies) has fractured the lithologies over historic mine workings and developed enhanced hydraulic connectivity within the strata, which has the effect of increased responsiveness of the regional groundwater table to wet / dry period influences.

## 7. FIELD AND LABORATORY INVESTIGATIONS

### 7.1 Cataract Creek

Cataract Creek field pH, electrical conductivity, temperature, dissolved oxygen and oxidation / reduction potential has been monitored since August 2008 at locations shown in **Table 2**.

Stream monitoring sites CC3 and CC4 lie upstream of the M1, whilst CC5 lies downstream of the Motorway as shown in **Figure 6**.

**Table 2 Cataract Creek Monitoring Sites**

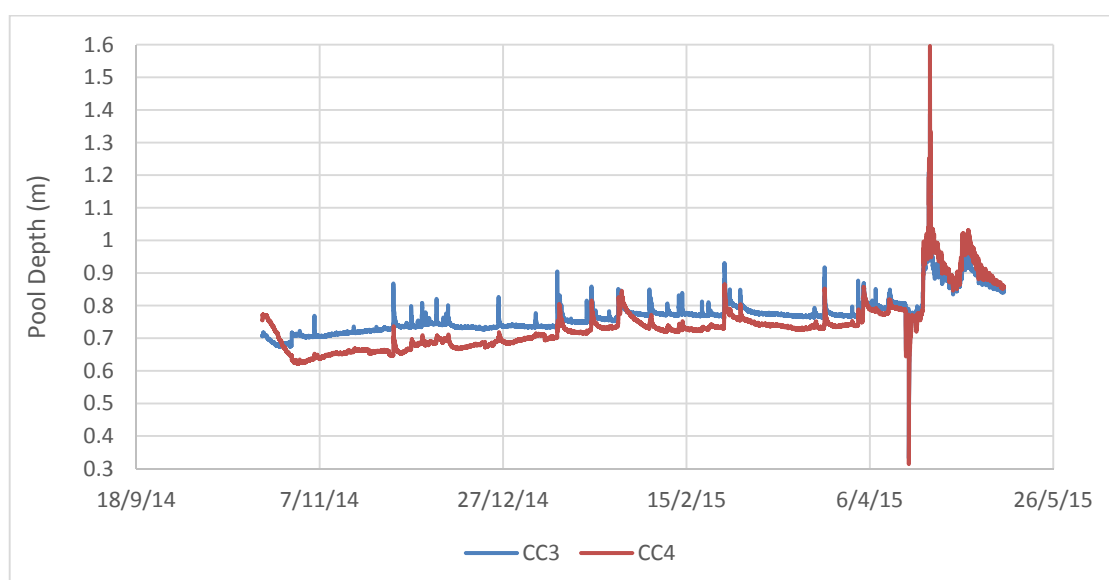
SITE	E (MGA)	N (MGA)	DESCRIPTION
<b>CC3</b>	303937	6196961	Northern tributary junction, east of Motorway
<b>CC4</b>	303964	6196992	Southern tributary junction, east of Motorway
<b>CC5</b>	303852	6197005	Cataract Ck, west of Motorway

NOTE: Co-ordinates supplied from GPS

#### 7.1.1 Stream Flow

Stream pool depth and available flow monitoring upstream of the current M1 at tributary CC3 and CC4 are shown in **Figure 7**.

It should be noted that due to the sand based channel which allows significant underflow, the width of the channel, and equipment installation difficulties, no stream pool depth or flow monitoring has been conducted to date at CC5.



**Figure 7 Cataract Creek Flow**

Volumetric stream flow has also been manually monitored at each transect location during each site inspection events at the monitored transect locations, and has been converted to

a continuous volumetric flow at selected sites as much as possible with current data.

The assessment indicates that baseflow comprises 32% of total flow in Cataract Creek.

Average daily stream flow is significantly larger than the median daily flow due to the short term impact of a small number of large surface flow events as shown in **Table 3** (WRM, 2014).

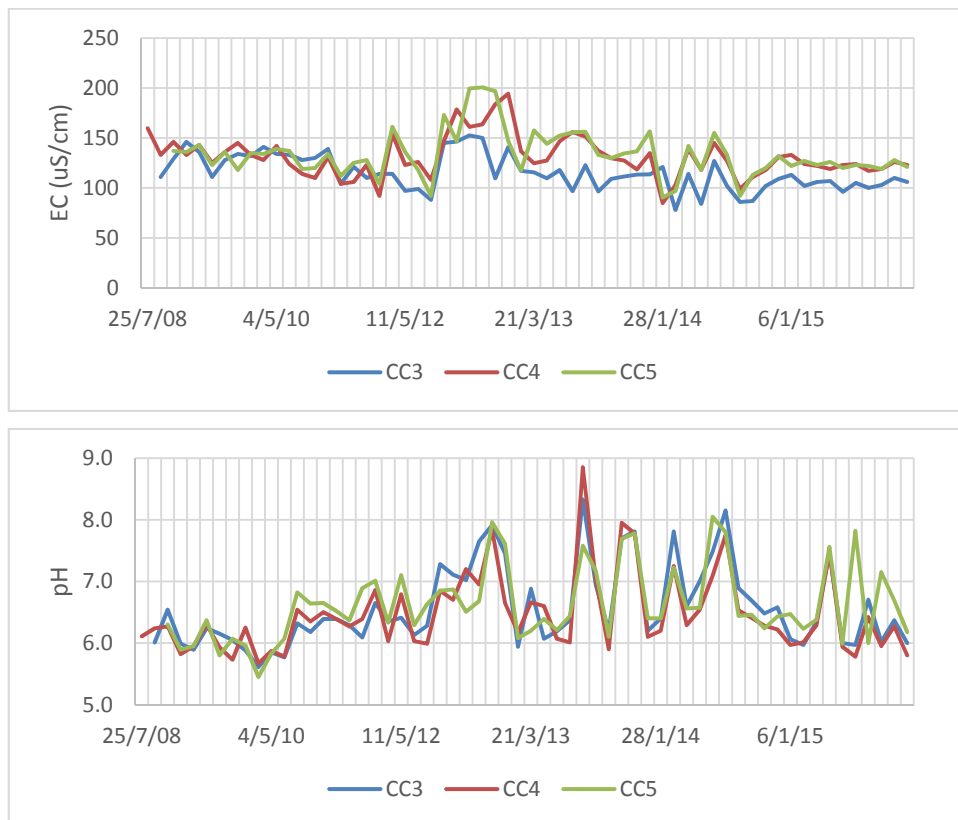
Based on WCL observations conducted since July 2008 and the calculated / extrapolated volumetric stream flow record (WRM, 2014) it is noted that Cataract Creek has not dried up or ceased to flow except for a short period on and around 22/8/12 to 24/10/2012 (downstream of the M1).

**Table 3 Cataract Creek Stream Flow Summary (ML/day)**

SITE	AVERAGE			MEDIAN		
	Runoff	Baseflow	Total	Runoff	Baseflow	Total
CC3	1.7	0.8	2.5	0.04	0.49	0.71
CC5	4.2	2.0	6.2	0.11	1.22	1.78

#### 7.1.2 Stream Water Quality

The field stream pH and electrical conductivity (EC) within Cataract Creek at Sites CC3, 4 and 5 is shown in **Figure 8**.



**Figure 8 Cataract Creek EC and pH**

Cataract Creek can exceed the ANZECC 2000 Upland Freshwater Stream and / or 95% Protection Level for Aquatic Ecosystems criteria (GeoTerra, 2014A) for;

- Total nitrogen, total phosphorous, aluminium, copper or zinc

## 7.2 Bellambi Creek

Bellambi Creek field pH, electrical conductivity, temperature, dissolved oxygen and oxidation / reduction potential was monitored 4<sup>th</sup> May 2016 at locations described in **Table 4** and shown in **Figure 6**.

**Table 4 Bellambi Creek Monitoring Sites**

SITE	E (MGA)	N (MGA)	DESCRIPTION
BC1	304965	6198285	Upstream of Motorway
BC2	304865	6198270	Downstream of Motorway

NOTE: Co-ordinates supplied from GPS

### 7.2.1 Stream Flow

No stream pool depth or flow monitoring has been conducted by WCL in Bellambi Creek.

### 7.2.2 Stream Water Quality

The field stream pH and electrical conductivity (EC) from samples collected by GeoTerra on 4<sup>th</sup> May 2016 within Bellambi Creek is shown in **Table 5**.

**Table 5 Bellambi Creek Field Water Quality**

SITE	pH	EC ( $\mu\text{S/cm}$ )	TDS	Na	Ca	K	Mg	Cl	F	HCO <sub>3</sub>	SO <sub>4</sub>	TN	TP	TSS
BC1	5.39	253	155	19	28	11	3.0	33	<0.1	90	11	1.5	0.02	64
BC2	5.47	148	85	21	3.6	1.0	2.8	38	<0.1	20	2	2.0	0.08	160
ANZECC	6.5 – 7.5	30 - 350	-	-	-	-	-	-	-	-	-	0.25	0.02	–

SITE	Fe <sub>T</sub>	Fe <sub>F</sub>	Mn <sub>T</sub>	Mn <sub>F</sub>	Cu <sub>F</sub>	Pb <sub>F</sub>	Zn <sub>F</sub>	Ni <sub>F</sub>	Al <sub>F</sub>	As <sub>F</sub>
BC1	9.2	0.11	0.10	<0.01	0.003	<0.001	0.011	<0.01	0.03	<0.01
BC2	14	0.04	0.26	0.14	0.002	<0.001	0.021	<0.01	0.02	<0.01
ANZECC	-	-	1.9	1.9	0.0014	0.0034	0.008	0.011	0.055	0.024

SITE	Li	Ba	Sr	Cd	Cr	Co	Se	Sb
BC1	0.013	0.016	0.18	<0.0002	<0.01	<0.01	<0.01	<0.01
BC2	0.004	0.013	0.02	<0.0002	<0.01	<0.01	<0.01	<0.01
ANZECC	-	-	-	0.0002	1.0 as Cr(VI)	-	0.011	-

**NOTE:** all units in mg/L except as shown      T = total      F = 0.45 $\mu\text{m}$  filtered

ANZECC 2000 default trigger values for risk of adverse effects from physical and chemical stressors in SE Aust. Upland Rivers or Upland Freshwaters SE Aust streams

(highlighting indicates values outside ANZECC 2000 criteria)

Based on the monitoring done to date, Bellambi Creek was outside, or exceeded, the ANZECC 2000 Upland Freshwater Stream and / or 95% Protection Level for Aquatic Ecosystems criteria for;

- pH, total nitrogen, total phosphorous, copper and zinc



### 7.3 Upland Swamps

A summary of swamps within the Study Area is contained in **Table 6**.

**Table 6 Study Area Swamps**

Swamp	Size (ha)	Previous Subsidence (m)	E	N	Depth (mbgl)	Lithology
<b>Ccus1</b>	4.81	0.6	303500	6196460	0.81 – 1.27	humic sandy clay / wthrd sast
<b>Ccus2</b>	1.21	1.8	303745	6196095	1.60	humic sandy clay / wthrd sast
<b>Ccus6</b>	2.05	2.0	303165	6196790	1.2	weathered sast
<b>Ccus15</b>	0.06	<0.2	303080	6196330	0.89	humic sandy clay / wthrd sast
<b>Ccus17</b>	0.07	<0.2	303110	6196315	0.95	humic sandy clay / wthrd sast
<b>Ccus20</b>	0.55	<0.2	303540	6196560	0.73	humic sandy clay / wthrd sast

Ten shallow hand auger holes have been drilled in the vicinity of the M1, with eight piezometers installed as some holes were too shallow, dry or did not encounter swamp materials within a designated swamp domain. In addition, SP1 was installed in colluvial sandy clay down slope of swamp Ccus6.

Swamp Ccus1, 15, 17 and 20 are located either over or next to the proposed road works area at Brokers Nose and drain to the north into 1<sup>st</sup> order gullies to Cataract Creek as shown in **Figure 9**.

All four swamps have been undermined by Bulli Seam first workings in the early 1900's and subsequently by Bulli pillar extraction and subsequently Balgownie longwalls up to the early 1980s.

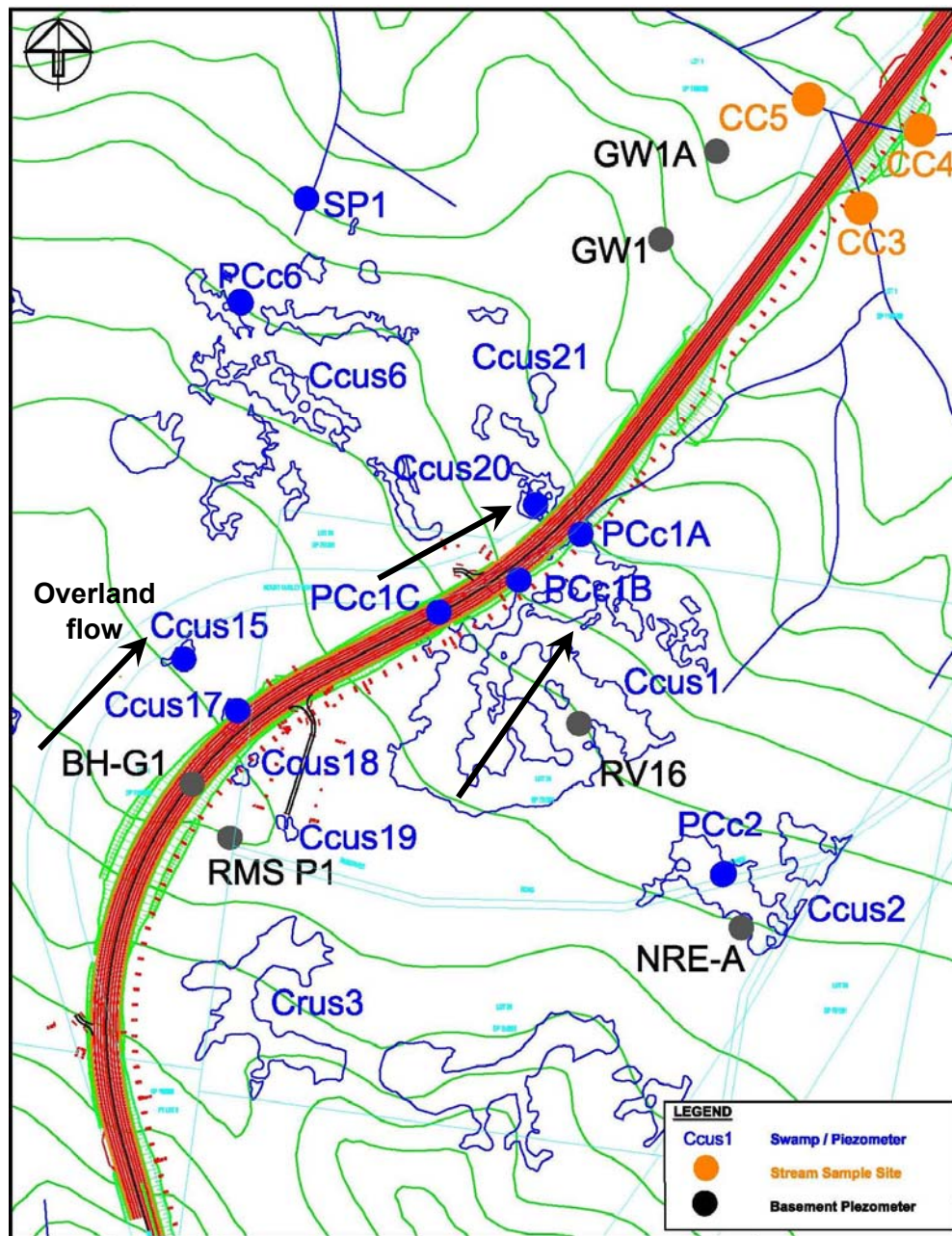
Three swamps have been predominantly dry since the piezometers were installed (Ccus15, 17 and 20) and are relatively small and irregularly shaped with little water storage capacity. Short lived periods of connate water occur in the generally dry swamps after sustained and significant rainfall. The three dry swamps contain limited humic material to a maximum depth of 0.95m and would undergo evapotranspiration as well as rapid drainage after heavy or prologed rainfall, with overland seepage outflow to a northerly draining gully then to Cataract Creek.

The upper and mid reach of the larger (4.81ha) swamp Ccus1 is predominantly dry, except for short lived periods after prolonged and significant rainfall, however the lowermost piezometer (PCc1A) is permanently saturated, with a water level of 0.47m bgl. The swamp in the vicinity of PCc1A contains humic material from 0.81 – 1.27m deep and would undergo evapotranspiration as well as rapid drainage after heavy or prologed rainfall, with overland seepage outflow to a northerly draining gully then to Cataract Creek.

SP1 is located to the west of the M1 and overlies the edge of a pillar extraction area in the Bulli Seam as well as Longwall 9 in the Balgownie workings. The piezometer undergoes evapotranspiration as well as rapid drainage after rainfall with overland seepage outflow to a northerly draining gully then to Cataract Creek. It is possible that adverse effects due to prior subsidence may be evident. However, as the piezometer is located in a sandy clay soil / weathered sandstone profile, with no humic matter and numerous shallow outcropping or

subcropping sandstone outliers, it is interpreted that the colluvial soil profile has little storage capacity and drains / evaporates rapidly as a result.

All swamp piezometers containing water are used to measure groundwater levels via data loggers and to enable sampling and assessment of field and laboratory water quality parameters. The data loggers are downloaded at varying intervals, with usually no more than one month between readings during the commissioned study period.



**Figure 9** Brokers Nose Area Swamp and Sandstone Piezometers

Drillhole depth and piezometer construction details are shown in **Table 7**.

**Table 7 Swamp Piezometers**

Bore	Swamp	Installed	E	N	Depth (mbgl)	Intake (mbgl)	Intake Lithology
PCc2	Ccus2	May 12	303745	6196095	1.60	1.1 – 1.6	humic sandy clay / wthrd sast
	Ccus2#	May 12	303735	6196100	-	Dry at 0.75	weathered sandstone
	Ccus2#	May 12	303730	6196080	-	Dry at 0.75	weathered sandstone
PCc6	Ccus6	Mar 12	303165	6196790	1.2	0.7 – 1.2	weathered sast
PCc15	Ccus15	May 16	303078	6196332	0.89	Dry at 0.89	humic sandy clay / wthrd sast
PCc17	Ccus17	May 16	303110	6196315	0.95	Dry at 0.95	humic sandy clay / wthrd sast
PCc20	Ccus20	May 16	303541	6196562	0.73	Dry at 0.73	humic sandy clay / wthrd sast
PCc1A	Ccus1	May 16	303577	6196483	1.23	1.0 – 1.23	humic sandy clay / wthrd sast
PCc1B	Ccus1	May 16	303498	6196447	0.84	Dry at 0.84	humic sandy clay / wthrd sast
PCc1C	Ccus1	May 16	303405	6196413	0.81	Dry at 0.81	humic sandy clay / wthrd sast
SP1	No swamp	Mar 12	303245	6196955	0.60	0.1 – 0.6	sandy clay / wthrd sast

**NOTE:** AMG co-ords based on GPS readings

# shading indicates a dry hole with no piezometer

### 7.3.1 Swamp Water Levels

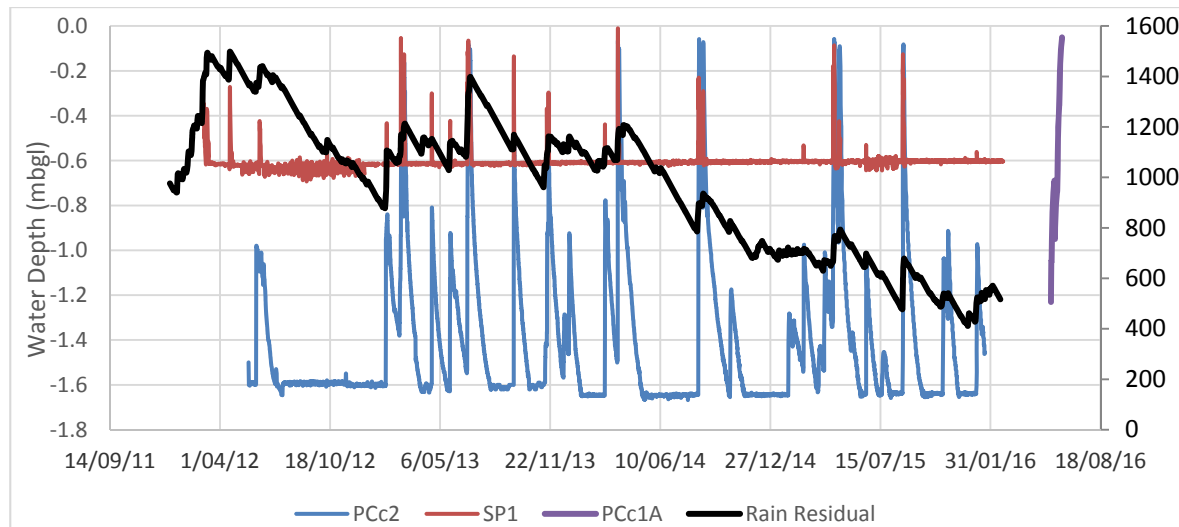
Water levels from monitored swamp piezometers in the Brokers Nose area, as well as SP1 are shown in **Figure 10**.

None of the Brokers Nose swamps to the east of the current M1 have been undermined by underground coal mining since the early 1980s.

No evidence of effects or impacts on swamp water levels, water retention, swamp desiccation or outflow discharge that could potentially be linked to mining induced subsidence in the monitored swamps has been observed (Biosis, 2014A) in any swamps in the vicinity of the M1.

Swamp piezometer PCc1A, which is the most downgradient piezometer in swamp Ccus1, contains a variable water level, whereas the remaining piezometers in the mid and upgradient reach of Ccus1 as well as Ccus15, 17 and 20 are essentially dry, except for short periods following significant and prolonged rain as was observed between 4 and 6 June when an east coast low storm dumped 329mm over 3 days.

In these periods the entire soil profile of the study area, including both permanently wet and the generally dry swamps (ie Ccus15, 17 and 20, as well as the upper reaches of Ccus1) become saturated, however, areas outside of the lower reach of Ccus1 do not hold water for long, with little differentiation between the “dry” swamps outlined above and the surrounding non swamp, sandy clay, sandstone derived soils.



**Figure 10 Swamp Water Levels and Rainfall**

### 7.3.2 Swamp Water Chemistry

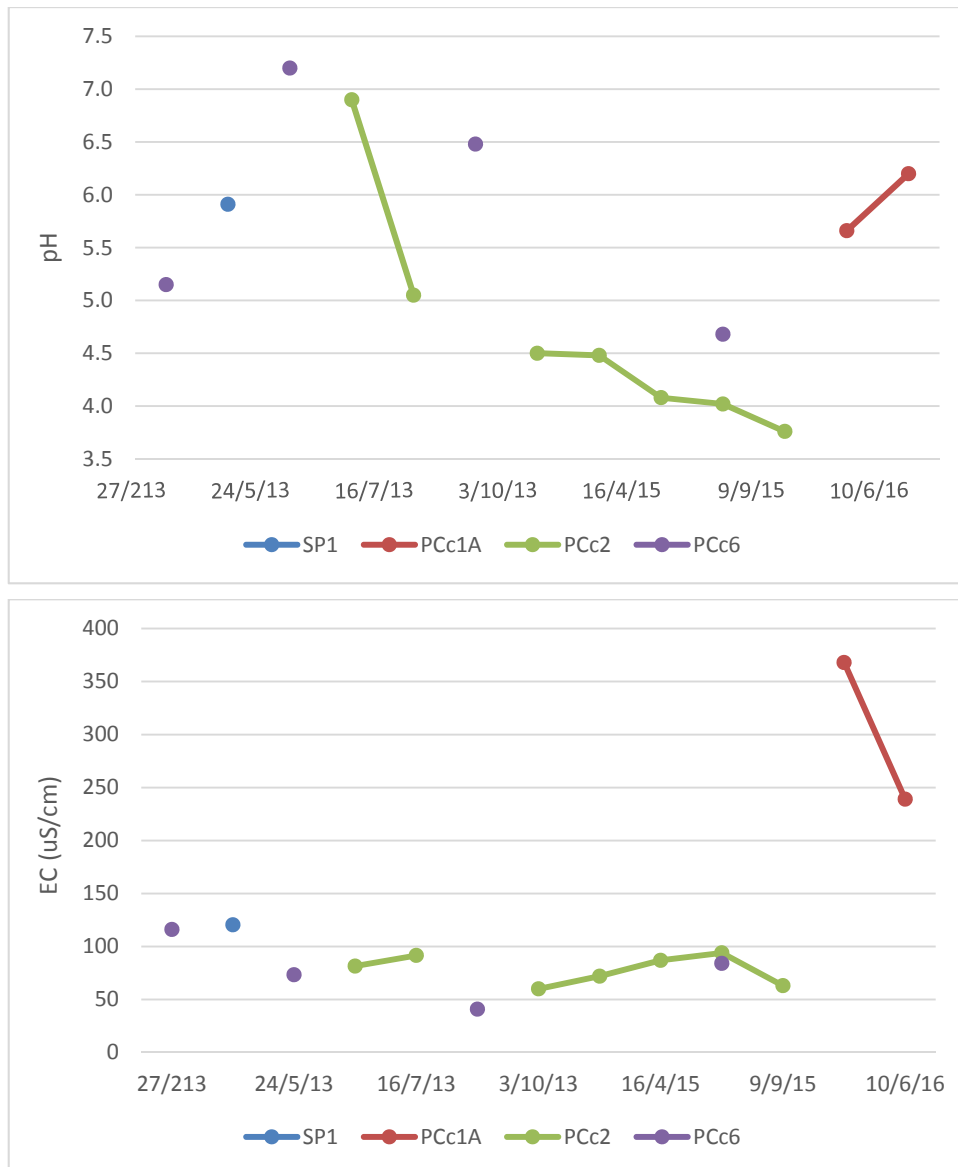
The Cataract Creek catchment swamps within the Brokers Nose area (when they contain standing water) have electrical conductivities (EC) ranging from 40 – 370 $\mu$ S/cm, with the salinity varying in relationship to rainfall recharge that occurs prior to sampling, along with the degree of brackish seepage from the weathered Hawkesbury Sandstone.

The pH ranges from 3.6 – 7.1 as shown in **Figure 11**.

The generally dry swamps had a short lived period of limited water levels after the early June east coast low storm, with PCc1B and C having pH between 4.42 and 6.2 and EC ranging from 94 - 239 $\mu$ S/cm. At the same time PCc15 and PCc17 had a pH of 5.21 and 5.25, and EC of 69 and 82 $\mu$ S/cm respectively

Monitoring and laboratory analysis indicates the swamp salinity is within the acceptable range for potable water, however it is generally outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for;

- filtered copper, lead, zinc, nickel, and occasionally aluminium (where its pH exceeds 6.5, which rarely occurs), as well as;
- total nitrogen, and total phosphorous.



**Figure 11 Swamp Field Water Quality**

#### 7.4 Groundwater

Extensive drilling, piezometer installation, pump out and falling head tests, packer tests, installation of vibrating wire piezometers, as well as groundwater level and water chemistry monitoring has been conducted within the proposed Stage 1 (Brokers Nose) road works area by WCL.

The data was used to develop a groundwater model and enable assessment of the hydrogeological characteristics of the Russell Vale colliery lease area (GeoTerra / GES, 2015).

RMS commissioned GeoTerra to assess the shallow Hawkesbury Sandstone on the Brokers Nose track, with the borehole being completed with an open standpipe piezometer to 15m below surface.

A summary of the installed piezometers is presented in **Tables 8** and **9**, with their locations shown in **Figure 9**.

The RMS also drilled a cored borehole (BH-G1) to 10.5mbgl in the centre of the proposed roadworks area along the Brokers Nose track, however no piezometer was installed and the hole was backfilled.

**Table 8 Open Standpipe Piezometers**

Bore	Install. Date	E	N	Depth (m)	Intake Interval (mbgl)
<b>WCL NRE A</b>	21/11/2009	303692	6196033	47	24 - 47
<b>WCL GW1A</b>	22/8/2012	303742	6196983	27	21 - 27
<b>RMS P1</b>	3/5/2016	303149	6196144	15	11 - 15

**Table 9 Vibrating Wire Piezometers**

Piezometer	E	N	Depth (mbgl)	Intakes (mbgl)
<b>NRE A VWP</b>	303680	6196034	153	45(mid HS) 60(low HS) 75(up BS) 140(mid BS)
<b>GW1</b>	303693	6196913	107.1	18 (BS) 30 (BS) 45 (BS) 63 (BS) 93 (BS) 125 (BS) 140 (SPCS) 165 (SS)
<b>RV16</b>	303567	6196288	322.2	22 (HS) 52(BHCS) 92 (BS) 132(BS) 197(SPCS) 242(SS)

**NOTE:** HS - Hawkesbury Sandstone NP - Newport Formation BHCS - Bald Hill Claystone  
BS - Bulgo Sandstone SPCS - Stanwell Park Claystone SS - Scarborough Sandstone

Under clause 18 and Schedule 5 of the *Water Management (General) Regulation 2011*, a Water Access License *under the Water Management Act 2000* was not required for the installation of the vibrating wire piezometer bores, however, all relevant approvals from Water-NSW (or its predecessor, the Sydney Catchment Authority) were obtained prior to drilling on their land.

## 7.5 Open Standpipe Shallow Groundwater Levels

Water level variability has been measured by WCL in open standpipe piezometers in the upper Hawkesbury Sandstone since mid-November 2009 in the Brokers Nose area.

The data indicates the strata is highly responsive to rainfall, principally where it is affected by subsidence related fracturing over the mine workings.

The shallow sandstone piezometers show a variable responsiveness to climatic variability and rainfall recharge that replicates, in a subdued manner, the variability of the rainfall residual plot.

Contour plotting indicates a general flow toward Cataract Reservoir (GeoTerra / GES, 2015).

### 7.5.1 RMS P1

RMS P1 was drilled approximately 50m east of the proposed road works near the Brokers Nose track on a ridge in Hawkesbury Sandstone over an area located between the Balgownie longwall and the Bulli Seam pillar extraction areas.

Subsidence related tension cracks would be located in the vicinity of P1, with a resultant



high vertical hydraulic connectivity caused by horizontal tensional stretching of the shallow overburden (SCT Operations, 2014), although no cracks were specifically identified in the field.

P1 was drilled by the dry hammer method to 15mbgl in Hawkesbury Sandstone. The drilling indicated a short, slightly wetter zone at 8.1 – 8.2mbgl, which is probably related to a bedding plane discontinuity of joint zone (which could not be recognised directly due to the drilling method used) and a moist drill return zone at 13 - 15mbgl.

After drilling the bore was left to stand overnight, and the water level rose to 6.2mbgl.

It should be noted, however, that the monitored water level in a piezometer can be affected by semi-confined head pressures, and can be higher than the intercepted aquifer. After a piezometer is installed, the subsequent water level measurements indicate a combination of head pressure in the aquifer, variability of recharge and other associated factors.

The slotted piezometer intake and gravel pack was subsequently sealed with bentonite and the water level stabilised at 12.60mbgl as shown in **Figure 12**.

The 8.1- 8.2mbgl intake is a perched, ephemeral and limited extent inflow zone, whilst the 13mbgl zone is probably the upper reach of the underlying regional water table.

The reduction in water depth after the piezometer intake was sealed indicates that, in the Brokers Nose area, the regional groundwater aquifer is below the 6.5m deep excavation zone of the proposed road works near the Brokers Nose track, and that the regional aquifer lies beneath the maximum roadworks excavation depth of 10.5m.

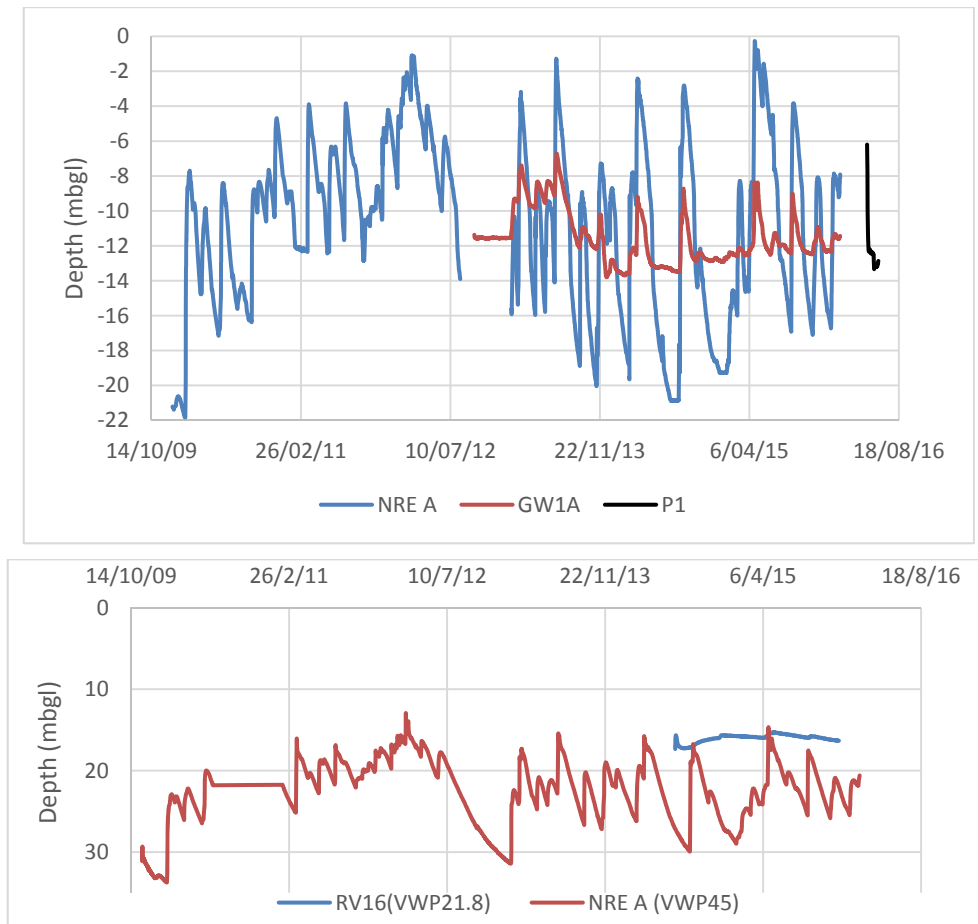
A nearby, water lubricated, cored hole (BH-G1) drilled by the RMS to 10.5m in the centre of the proposed roadworks along the Brokers Nose track identified significant core loss zones to approximately 5.3m below surface and numerous fracture zones.

Although P1 has not been monitored for a sufficient period, it is likely to have a strong correlation to the rainfall residual plot.

Groundwater level plots in **Figure 12** indicate that NRE A (VWP and OSP) have high water level variability due to their location on the highly fractured ridge line near the Brokers Nose track, and their location over the edge of the Bulli and Balgownie Seam workings, whilst RV16, which is located off the top of the watershed and over the pillar extracted Bulli and between Longwalls 5 and 6 in the Balgownie workings, has a lower degree of strata fracturing and associated responsiveness to rainfall recharge.

The plot for GW1A indicates an intermediate responsiveness to rainfall.





**Figure 12 Groundwater Levels**

### 7.5.2 Groundwater Chemistry

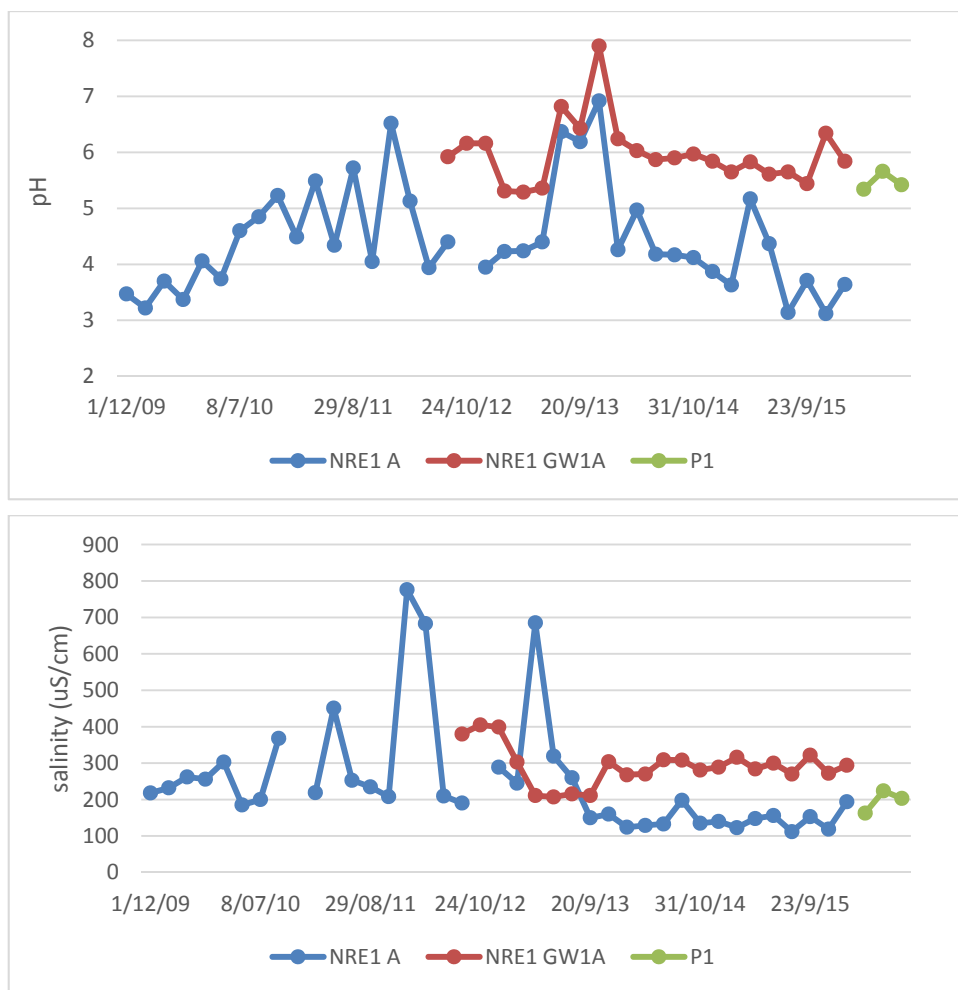
Based on data supplied by WCL and monitoring of RMS P1, groundwater in the Hawkesbury Sandstone in the Brokers Nose area ranges from 112 - 776 $\mu$ S/cm with a pH from 3.1 – 7.9 as shown in **Figure 13**.

The moderate pH acidification and low salinity indicate meteoric rainfall recharge into the Hawkesbury Sandstone, with the salinity and pH being typical of similar lithologies in the Southern Coalfields.

The lower salinity and more acidic pH in NRE A and RMS P1 compared to GW1A indicate that the two piezometers in the highly fractured zone near the Brokers Nose track have a higher dilution by rainfall and greater fresh mineral interaction within the fractured rock.

On the basis that the shallow groundwater discharges through seeps into the local streams, monitoring indicates the groundwater salinity is generally within the acceptable range for potable water, however it is predominantly outside the ANZECC 2000 South Eastern Australia Upland Stream criteria for pH and can be above the ANZECC 2000 95% Species Protection Level for Freshwater Aquatic Ecosystem Guidelines for:

- filtered copper, lead, zinc and aluminium (where the pH exceeds 6.5, which rarely occurs), as well as;
- total nitrogen and total phosphorus.



**Figure 13** Hawkesbury Sandstone Salinity and pH

## **8. POTENTIAL EFFECTS, IMPACTS AND CONSEQUENCES OF THE PROPOSED M1 RE-ALIGNMENT**

### **8.1 Stream Flow and Water Quality**

#### **8.1.1 Cataract Creek**

The road works and associated excavations are proposed to be cut to a maximum depth of 10.5m and width of up to approximately 85m in the vicinity of the Brokers Nose (Stage 1) area ridge line within the Cataract Creek catchment.

None of the Brokers Nose works area will intersect designated order stream channels as it is within an area of colluvial overland sheet wash headwaters and limited scale upland swamps, which subsequently drain into 1<sup>st</sup> order channels of Cataract Creek.

As shown in **Figure 6**, a proposed up to 10.5m deep excavation at Works Area 1 is located to the north of Brokers Nose over an approximately 380m reach within a northerly draining, 1<sup>st</sup> order stream that drains to the north into Cataract Creek.

A further excavation area at Works Area 2 is situated over an approximate 210m width containing two south easterly draining, 1<sup>st</sup> order stream that drain to the south into Cataract Creek.

As the Brokers Nose works area within the Cataract Creek catchment is not planned to intersect designated stream channels, there should be no definitive impact on the local streams and main channel of Cataract Creek except for potential turbid / sediment containing runoff wash from the works if the proposed sediment / runoff management measures do not work effectively.

As such, there should be no adverse effect on the quantity or quality of water draining into Cataract Creek, and subsequently, Cataract Reservoir.

#### **8.1.2 Bellambi Creek and Allen Creek**

A reach of four excavation / cut back works areas are proposed in the Bellambi and Allen Creek catchments, however as the road essentially follows the ridge watershed, no designated order streams are proposed to be excavated.

As the works areas are not planned to intersect designated stream channels, there should be no definitive impact on the local streams and main channel of Bellambi or Allen Creeks, except for potential turbid / sediment containing runoff wash from the works if the proposed sediment / runoff management measures do not work effectively.

Although the excavation areas are proposed to cut into existing 1<sup>st</sup> order channels, with appropriate water diversion and sediment controls in place during and after the excavation and road construction period, there should be no adverse effect on the quantity or quality of water draining into Bellambi or Allen Creek, and subsequently, Cataract Reservoir.

### **8.2 Stream Bed Alluvium**

Sediment wash may potentially accumulate in the main stream beds if sediment control measures used within the works areas are not effective.

### 8.3 Upland Headwater Swamps

Upland swamps, which will be directly affected by the proposed works are all contained in the Brokers Nose area.

The following sections outline the potential effects on swamps adjacent to, or within, the proposed works area.

**Figure 14** indicates the swamps that may be affected by the proposed works.

#### 8.3.1 Ccus1

Approximately 8% of the 4.81ha within Ccus1 is planned to be either covered over by backfill in the lower and mid reach or excavated upper reach of the western swamp edge by the proposed works. The covered / excavated area lies on the western swamp edge, which drains downslope to the northeast, parallel to the current and proposed M1 roadway.

The shallow piezometers indicate the proposed road works backfill covered area within and adjacent to the swamp ranges from 0.81 – 1.27m deep, with the swamp being composed of humic sandy clays. The mid and up slope piezometers Ccus1B and Ccus1C were generally dry, whilst the lower area at Ccus1A is permanently saturated, with a water level ranging from 0.76 – 0.08m below surface in the 1.23m deep piezometer.

There is a 27m ground surface height differential between the top and bottom of Swamp Ccus1, adjacent to, or within, the works area. The upper reaches of the swamp are fringed by shallow (<1m high) rock ledges which flow into a small 1<sup>st</sup> order gully which drains to the north east, parallel to the current and proposed road.

The proposed roadworks are planned to cover over the lower and mid reach of the western edge of Ccus1 with up to approximately 4m of road base and backfill, whilst up to 2.4m will be excavated into the southern, upgradient, dry, western portion of Ccus1.

The built up areas will potentially enable some ponding of water along the eastern edge of the road batter, whilst the excavated areas could drain a localised western portion of the swamp into the road and associated excavation area.

The potential lateral extent of any swamp ponding and associated increased saturation in the built up areas could be limited by installing toe drains to enable any ponded surface runoff to be drained downslope, whilst the potential dewatering of the southern, upslope swamp area is likely to be limited and ephemeral as that part of the swamp is predominantly dry.

The potential lateral extent of dewatering, if any, in the upslope, southern area is not accurately known with current data as the swamp has a highly irregular basal profile, where the swamp sediments are irregularly interspersed both laterally and horizontally within isolated areas of outcropping / subcropping sandstone.

#### 8.3.2 Ccus15

The 0.06ha swamp Ccus15, which is approximately 80m west of the proposed road re-alignment and approximately 25m east of the current M1, will not be affected by the proposed works as the drainage runoff in its catchment is to the north east, and parallel to, the current and proposed road.

The swamp contained water for a short period following an east coast low storm which dumped 329mm over 3 days between 4 and 6 June 2016, with the stored water quickly draining away into the local soil profile.

### 8.3.3 Ccus17

The 0.07ha swamp Ccus17 will be completely removed by the proposed roadworks as it lies within the excavation works area.

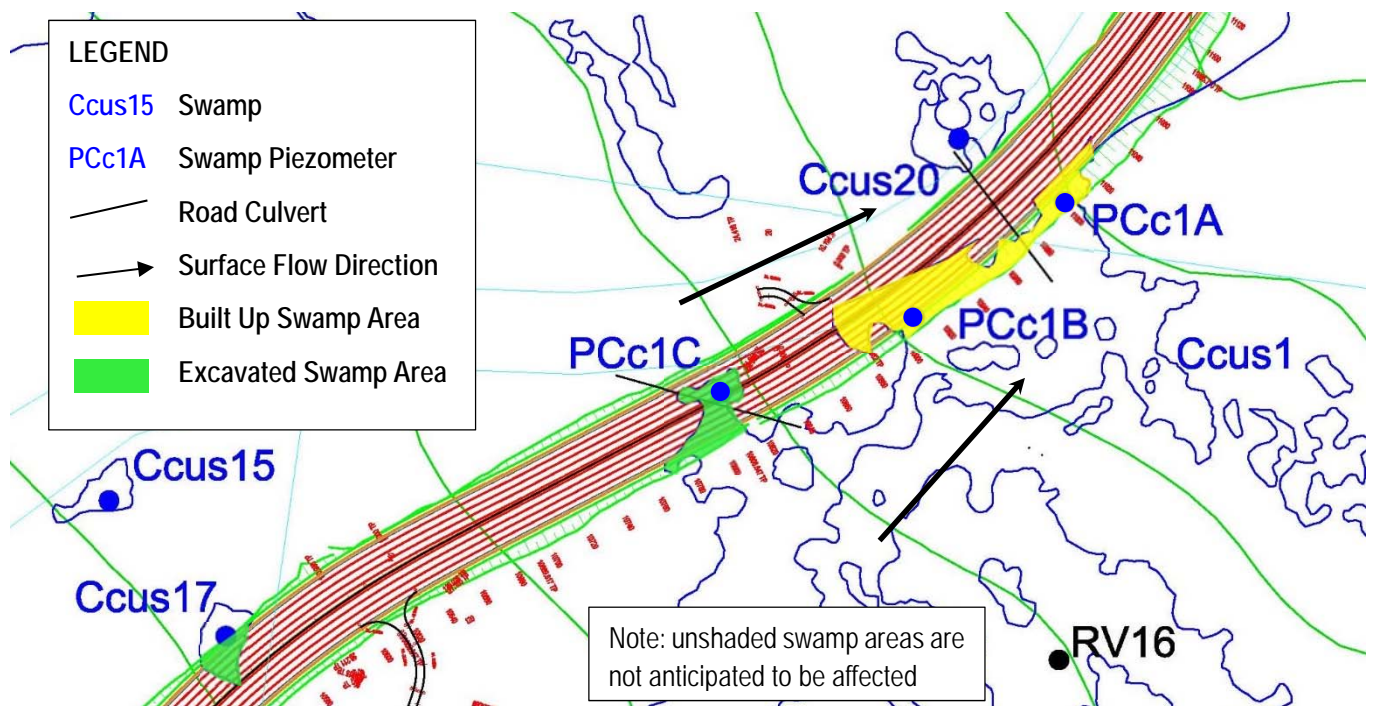
It has been measured up to 0.95m deep, with no standing water, although it could recharge then subsequently lose its standing water in relatively short time frames after sufficient rainfall (which has not occurred in the study period).

The swamp contained water for a short period following an east coast low storm which dumped 329mm over 3 days between 4 and 6 June 2016, with the stored water quickly draining away into the local soil profile.

### 8.3.4 Ccus20

Ccus20, which is 0.55ha in extent, is located immediately west and downslope of the current and proposed works area, and it is not anticipated to be affected by the proposed works as there is no planned excavation of the swamp, although it may be disturbed if any of the work area, or runoff from it, extends into the swamp.

The swamp contained water for a short period following an east coast low storm which dumped 329mm over 3 days between 4 and 6 June 2016, with the stored water quickly draining away into the local soil profile.



**Figure 14 Potentially Affected Swamp Areas**

## 8.4 Shallow Groundwater

### 8.4.1 Perched Hawkesbury Sandstone

Perched, ephemeral, shallow groundwater within the upper Hawkesbury Sandstone will undergo a reduction in both water level and seepage longevity from the isolated bedding plane / joint / fracture based seeps that lie above the regional Hawkesbury Sandstone aquifer as a result of the up to 10.5m deep excavation.

However, as the perched seeps desiccate after extended dry periods, the effect on the mostly disconnected, perched aquifers will be minor.

Enhanced leakage from the perched aquifers into the excavation will occur, with the subsequent seepage rate into local streams being essentially unaffected, unless evaporation off the road surface and associated rock face drainage system occurs, whilst recharge into the underlying regional aquifer will be reduced for the perched aquifers intersected or removed by the works.

The proposed works are not anticipated to have a significant overall effect on recharge to the underlying regional aquifer, stream baseflow or stream water quality where the currently temporary aquifers seep into local catchments.

### 8.4.2 Upper Hawkesbury Sandstone

The upper Hawkesbury Sandstone regional aquifer is located at or deeper than 13m below surface in the Brokers Nose area, which is below the proposed excavation depth of the M1 re-alignment works.

As a result, it is not anticipated that the proposed roadworks will adversely affect the regional groundwater system.

### 8.4.3 Shear Zones

Lateral movement of hillsides toward the valley floor and associated horizontal to sub-horizontal shearing of the strata, along with vertical tensile fracturing along the ridge line has been observed in the Brokers Nose area (SCT Operations, 2014) within historic and current mine subsidence areas.

This mechanism is inferred to occur where lateral shear movement, which is not necessarily associated with pre-existing bedding plane or strata discontinuities, is mobilised following periods of intense rainfall.

The horizontal shearing of pre-existing natural bedding planes and vertical joints is inferred to have occurred in association with mining induced subsidence and hillslope dilational movement following extraction of the Balgownie and Bulli Seams.

The inferred shear plane (or multiple en-echelon planes) may have been re-mobilised to the west of the current M1 following extraction of Longwalls 4 and 5 in the Wongawilli Seam, particularly after heavy rain in early to mid-2014.

The main horizontal shearing is interpreted to be located 6 – 10m below the valley floor and may extend from the creek bed, under the subsided hillslope within the zone of subsidence for up to approximately 400 - 450m away from the creek. The vertical tensile fracturing also tends to be located and focussed along ridge lines.

A definitive assessment of the location, size, extent and nature of the horizontal shear planes and vertical fracture zones in the proposed works area is not well known at present, however intersection of these zones by the roadworks could enhance the potential lateral



drainage of both surface runoff and perched shallow sandstone seepage into the excavation.

#### 8.4.4 Stream and Groundwater System Connectivity

Monitoring of water level trends in piezometer NRE A over the multi-seam mined area indicates the upper Hawkesbury Sandstone down to the Upper Bulgo Sandstone lithologies have an enhanced response to rainfall recharge. However, no adverse effect on stream flow has been observed as the headwater tributaries and main channel of Cataract Creek have had continuous flow throughout the WCL monitoring period.

It is also possible that, where they exist, or have been generated as a result of dilational movement of the hillslope after subsidence, perched and / or phreatic hillslope seepage outflow points may be relocated to lower elevations in the catchment due to the dilational fracturing of the hillslopes and associated hillslope basal shear zone movement resulting from valley closure.

#### 8.4.5 Shallow Groundwater Contribution to Swamps

Although no direct installation and monitoring of shallow ephemeral groundwater systems and their contribution to swamp water levels has been conducted to date, monitoring of water levels within previously (and potentially) undermined swamps has been assessed by Biosis (2014A), whilst their discharge outflow rates have been determined by WRM Water and Environment (2015), who ascertained that the swamps are not, as is widely assumed, significant, long term contributors of baseflow to stream flow within the Russell Vale Colliery lease area.

#### 8.4.6 Groundwater Chemistry

There may be some localised increased iron hydroxide precipitation and limited lowering of pH if the groundwater within excavated areas is exposed to the atmosphere on unweathered rock faces through dissolution of unweathered iron sulfide minerals in the deeper, unweathered portion of the excavation.

The degree of iron hydroxide and pH change is difficult to predict, and can range from no observable effect to a distinct discolouration of seepage water. The discolouration does not pose a health hazard.

As a result of the proposed works, pH acidification of up to 1 unit may occur, however the change may be reduced if the aquifer has sufficient carbonate or bicarbonate buffering capacity.

Outside of isolated iron hydroxide seepages, no groundwater of adverse quality is anticipated to discharge into the excavated area and then into local streams or groundwater systems.

### 8.5 Cataract Reservoir

As both the water volume and quality draining into local streams out of both the current M1 roadway, as well as the proposed works and final motorway area is not anticipated to change from the current situation, it is therefore not predicted that water volumes or quality draining into Cataract Reservoir will be observably affected by the proposed works



## 9. WATER LICENSING

### 9.1 Groundwater

The Project is covered by the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*, which applies to 13 groundwater sources within Management Zone 2 of the Sydney Basin Nepean Groundwater Source. This includes all aquifers below the ground surface (clause 4), as well as alluvium, weathered and basement rocks.

The RMS currently does not hold a groundwater licence under the Water Management Act for the existing roadway.

For the purposes of the Act, an ‘aquifer’ is defined as “a geological structure or formation, or artificial landfill that is permeated with water or is capable of being permeated with water”.

As the proposed road works will intersect the shallow, ephemeral, perched aquifers, but not the deeper, regional Hawkesbury Sandstone aquifer, the effects on the shallow aquifer/s is deemed to be a water “take”.

Since the Groundwater WSP applies to all aquifers, the RMS will require a Water Access Licence (WAL) for all groundwater taken by the roadway and associated excavations.

The total licensing entitlement required will need to cover the maximum groundwater make resulting from the proposed and existing works.

Based on the fact that the perched, shallow, ephemeral seeps are of limited seepage duration, extent and depth, the maximum groundwater inflow to the works area is likely to be small, however this inflow figure has not been calculated due to insufficient data.

### 9.2 Surface Water

The Project is located within the area covered by the *Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources 2011* (Unregulated River WSP). The Unregulated River WSP includes six water sources, with the proposed works area located within the ‘Upper Nepean and Upstream Warragamba Water Source’.

Clause 4 of the Unregulated River WSP states that these water sources include all water:

- occurring naturally on the surface of the ground shown on the Registered Map, and;
- in rivers, lakes, estuaries and wetlands in these water sources.

The RMS currently does not hold a licence for surface water use in the existing M1 and proposed works area, however, as the surface runoff will be locally diverted by the proposed excavations and road re-alignment, rather than “taken” from the water source, it is likely the RMS will not need to obtain a WAL for the volume of surface water affected by this aspect of the works within the Upper Nepean and Upstream Warragamba Water Source.

However, other impacts give rise to licensing requirements include:

- reduction in base flows to streams due to drawdown;
- additional runoff that infiltrates into the groundwater system via subsidence induced shallow cracking;
- leakage from swamps; and
- loss of water from Cataract Reservoir due to depressurisation.

Backfilling over along with excavation and the associated drainage changes of the saturated lower reaches of the western 8% (approximately 0.4ha) of Swamp Ccus1 (and its associated depressurisation halo) along with full excavation of the 0.07ha Swamp Ccus17 is proposed.

Although the component of water stored in the swamps (particularly the lower elevation area of Ccus1) that will be within the excavated portion of the swamp will still drain into Cataract Creek, that water is deemed to have been “taken”.

Section 60I of the WM Act indicates that water is deemed to be taken even if it is returned to the water source. Although it is written in terms of mining, Section 60I states:

*“a person takes water in the course of carrying out a mining activity if, as a result of or in connection with, the activity or a past mining activity carried out by the person, water is removed or diverted from a water source (whether or not water is returned to that water source) or water is re-located from one part of an aquifer to another part of an aquifer”.*

Volumetric assessment of the potential annual stream flow affects that may occur due to the proposed works has not yet been assessed due to lack of site specific data.

## 10. NSW AQUIFER INTERFERENCE POLICY MINIMAL IMPACT CONSIDERATIONS

The Aquifer Interference Policy (AIP) prescribes minimal impact considerations which must be satisfied.

The minimal impact considerations for a water source vary depending on the nature of the water source (i.e. alluvial, coastal, fractured rock etc) and whether it is “highly productive groundwater” or “less productive groundwater”.

The minimal impact considerations for less productive porous rock (ground) water sources are presented in **Table 10** and for the perched, ephemeral aquifers in **Table 11**.

The aquifers are not considered to be “highly” productive as although they contain total dissolved solids of less than 1500mg/L in the Hawkesbury Sandstone, there are no water supply works that yield water at a rate greater than 5L/sec in the area.

**Table 10 NSW Minimal Impact Considerations for Less Productive Porous Rock Water Sources**

Minimal Impact Consideration	Assessment
<p><u>Water Table – Level 1</u></p> <p>Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan variations, 40m from any:</p> <p>a) high priority groundwater dependent ecosystem, or</p> <p>b) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or</p> <p>A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.</p>	<p>There are no:</p> <ul style="list-style-type: none"> <li>high priority groundwater dependent ecosystems, or;</li> <li>high priority culturally significant sites</li> </ul> <p>listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.</p> <p>The swamps are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE).</p> <p>There are no water supply works (i.e. groundwater bores) in the proposal area that will undergo more than a 2m decline.</p>
<p><u>Water Table – Level 2</u></p> <p>If more than 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:</p> <p>a) high priority groundwater dependent ecosystem; or</p> <p>b) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.</p> <p>If more than 2m decline cumulatively at any water supply work then make good provisions should apply.</p>	<p>Level 2 does not apply as Level 1 criteria is not exceeded</p>
<p><u>Water Pressure – Level 1</u></p> <p>A cumulative pressure head decline of not more than 40% of the “post-water sharing plan” pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.</p>	<p>There are no water supply works (i.e. groundwater bores) in the proposed works area that will undergo a greater than 40% post water sharing plan pressure head decline above the base of the water source, and no water supply work will undergo greater than 2m decline</p>
<p><u>Water Pressure – Level 2</u></p> <p>If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.</p>	<p>Level 2 does not apply as Level 1 criteria is not exceeded</p>

<p><u>Water Quality – Level 1</u></p> <p>a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity, and</p> <p>b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.</p> <p>Redesign of a highly connected surface water source that is defined as a “reliable water supply” is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above.</p> <p>c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.</p>	<p>The beneficial use category of the groundwater source will not be changed beyond 40m from the proposed works area.</p> <p>There are no highly connected surface water sources (alluvial aquifers) in the proposed works area</p> <p>There are no highly connected alluvial surface water sources defined as a reliable water supply within the proposed works area</p>
<p><u>Water Quality – Level 2</u></p> <p>If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.</p> <p>If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.</p> <p>Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters</p>	<p>Level 2 does not apply as Level 1 is not exceeded</p>

**Table 11 NSW Minimal Impact Considerations for Perched Ephemeral Aquifer Water Sources**

Minimal Impact Consideration	Proponent Response
<p><u>Water Table – Level 1</u></p> <p>Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan variations, 40m from any:</p> <p>c) high priority groundwater dependent ecosystem, or</p> <p>d) high priority culturally significant site listed in the schedule of the relevant water sharing plan, or</p> <p>A maximum of a 2 m decline cumulatively at any water supply work unless make good provisions should apply.</p>	<p>There are no:</p> <ul style="list-style-type: none"> <li>high priority groundwater dependent ecosystems, or;</li> <li>high priority culturally significant sites</li> </ul> <p>listed under Schedule 4 of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011.</p> <p>The swamps in the proposed works area are not classified as Temperate Highland Peat Swamps on Sandstone (which is high priority GDE).</p> <p>There are no water supply works (i.e. groundwater bores) in the works area that will undergo more than a 2m decline.</p>
<p><u>Water Table – Level 2</u></p> <p>If more than 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40m from any:</p> <p>c) high priority groundwater dependent ecosystem, or</p> <p>d) high priority culturally significant site listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.</p> <p>If more than 2m decline cumulatively at any water supply work then make good provisions should apply.</p>	<p>Level 2 does not apply as Level 1 criteria is not exceeded</p>
<p><u>Water Pressure – Level 1</u></p> <p>A cumulative pressure head decline of not more than 40% of the “post-water sharing plan” pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.</p>	<p>There are no water supply works (i.e. groundwater bores) in the proposed works area that will undergo a greater than 40% post water sharing plan pressure head decline above the base of the water source, and no water supply work will undergo greater than 2m decline</p>
<p><u>Water Pressure – Level 2</u></p> <p>If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister’s satisfaction that the decline will not prevent the long-term viability of the affected water supply works unless make good provisions apply.</p>	<p>Level 2 does not apply as Level 1 criteria is not exceeded</p>

<p><u>Water Quality – Level 1</u></p> <p>d) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and</p> <p>e) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity.</p> <p>Redesign of a highly connected surface water source that is defined as a “reliable water supply” is not an appropriate mitigation measure to meet considerations 1(a) and 1(b) above.</p> <p>f) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.</p>	<p>The beneficial use category of the groundwater source will not be changed beyond 40m from the proposed works area.</p> <p>There are no highly connected surface water sources (alluvial aquifers) in the proposal area</p> <p>There are no highly connected alluvial surface water sources defined as a reliable water supply within the proposal area</p>
<p><u>Water Quality – Level 2</u></p> <p>If condition 1(a) is not met then appropriate studies will need to demonstrate to the Minister’s satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.</p> <p>If condition 1(b) is not met then appropriate studies are required to demonstrate to the Minister’s satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.</p> <p>Condition 1(c) does not apply as there are no river bank or high wall instability risks and no need for low permeability barriers between the site and highly connected surface waters</p>	<p>Level 2 does not apply as Level 1 is not exceeded</p>

## 11. MONITORING, CONTINGENCY MEASURES & REPORTING

The RMS will prepare a Water Management Plan in accordance with conditions of Project Approval.

The Water Management Plan will include a surface water and groundwater monitoring program, which will include monitoring of stream water flows and quality, as well as groundwater levels and water quality.

### 11.1 Groundwater Levels

Piezometers to be included in the monitoring suite are shown in **Table 12**.

The suite is divided into standpipe and vibrating wire piezometers, with water level transducers and vibrating wire piezometers used to monitor standing water levels or pressure heads twice daily to assess variations in the colluvial and basement formations.

An agreement will need to be reached to enable Wollongong Coal to provide the data for piezometers NREA, GW1A and RV16.

**Table 12 Groundwater Level Monitoring Suite**

	Piezometer Type
<b>Basement</b>	
NREA, GW1A, RMS P1	Open Standpipe
NREA, GW1, RV16	VWP

**NOTE:** VWP = vibrating wire piezometer

Inclusion of additional groundwater monitoring locations and depths will be incorporated, if required, following discussions with the SCA and NOW.

Monitoring will also involve bi-monthly manual standing water level measurement in all open standpipe piezometers, at which time the loggers will be downloaded and re-initiated as shown in **Table 13**.

**Table 13 Standing Water Level Monitoring Method and Frequency**

Monitoring Site	Sampling Method	Frequency / Download	Units
Open standpipe piezometers	Water level logger / dip meter	twice daily / every 2 months	mbgl
Vibrating wire piezometer arrays	Vibrating wire piezometer	twice daily / quarterly	m head pressure

**NOTE:** mbgl = meters below ground level

### 11.2 Groundwater Quality

**Tables 14 and 15** present the parameters to be measured, frequency of monitoring and sampling method for groundwater quality monitoring, with monitoring to continue for an agreed period after the construction period has ceased.



**Table 14 Groundwater Quality Monitoring Parameters**

<b>ANALYTES</b>	<b>Units</b>	<b>FREQUENCY</b>
EC, pH	µS/cm, pH units	Every 2 months
(EC, pH) + TDS, Na, K, Ca, Mg, F, Cl, SO <sub>4</sub> , HCO <sub>3</sub> , NO <sub>3</sub> , Total N, Total P, hardness, Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd (metals filtered)	mg/L	Start / finish of works for piezometers near the works area, otherwise 1 sample per year

The frequency of monitoring will be reassessed after the works are complete as it may be possible, depending on results, to lengthen the intervals. The frequency of monitoring and the parameters to be monitored may be varied by NOW once the variability of the groundwater quality is established.

Groundwater samples should be collected at the start and finish of the works from piezometers adjacent to the works area and analysed at a NATA registered laboratory for major ions and selected metals.

It is anticipated that the groundwater monitoring program will be maintained in its current status, with agreed modification at the end of the works program after a review of all monitoring data has been conducted.

Additional piezometers may be added to the existing suite if required.

The groundwater monitoring program is anticipated to be extended beyond the active works period in order to assess the potential long term change in groundwater level recovery and quality changes for at least 12 months, or as agreed with the regulators.

**Table 15 Groundwater Quality Monitoring Method and Frequency**

<b>Monitoring Site</b>	<b>Sampling Method</b>	<b>Frequency</b>
Open Standpipe Piezometers	Pumped field meter readings	Every 2 months during the works period
Open Standpipe Piezometers	Pumped sample for laboratory analysis	Start / finish of the works

### 11.3 Rainfall

Daily rainfall data will be obtained from a local weather station for the duration of the works in the proposal catchment area.

### 11.4 Ongoing Monitoring

All results will be reviewed after the end of the works period and an updated monitoring and remediation program will be developed, if required, in consultation with NOW and DRE.

## 11.5 Quality Assurance and Control

QA/QC should be attained by calibrating all measuring equipment, ensuring that sampling equipment is suitable for the intended purpose, using NATA registered laboratories for chemical analyses and ensuring that site inspections and reporting follow procedures outlined in the ANZECC 2000 Guidelines for Water Quality Monitoring and Reporting.

## 11.6 Impact Assessment Criteria

### 11.6.1 Groundwater Levels

Impact assessment criteria investigation trigger levels should be initially set where a groundwater level reduction exceeds more than 10% of the saturated aquifer thickness over a 12 month period, compared to the minimum height within the last 12 months of data, excluding any short term recharge peaks.

Should the trigger be exceeded, the actual rate of change of water levels should be investigated to determine whether the change is solely subsidence induced or due to a range of other potential factors.

If a significant increase in the rate of water level decline is noted, based on interpretation by a qualified hydrogeologist, then an assessment should be conducted to determine the cause of the change (such as variation in climate or effects from adjacent mining operations) and to consider potential contingency measures that may be adopted.

### 11.6.2 Groundwater Quality

Groundwater quality impact assessment criteria are sourced from the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 2000) for Aquatic Ecosystems as shown in **Table 16**.

**Table 16 Groundwater Quality Impact Assessment Criteria**

Indicator	Irrigation Criteria
pH	<6.5 or >7.5 or >10% variation over 4 months compared to previous 12 months data
Conductivity	>10% variation over 4 months compared to previous 12 months data
TDS	>350mg/L or >10% variation compared to previous 12 months data
Total Nitrogen	>250µg/L or >10% variation compared to previous 12 months data
Total Phosphorus	>20µg/L or >10% variation compared to previous 12 months data

A trigger to assess the cause and effects of adverse groundwater quality changes should be implemented when there is a prolonged and extended non-conformance of the outlined criteria at a particular piezometer.

If a field parameter (pH, conductivity) is outside the designated criteria for at least six months in a sequence, or alternatively, exceeds its previous range of results by greater than a 10% variation for at least 4 months, then the cause should be investigated, and a remediation strategy should be proposed, if warranted.

The criteria and triggers should be reviewed after each 12 month block of data is interpreted and may be modified as appropriate, depending on the results.

If the impacts on the groundwater system resulting from future effects within the works area are demonstrated to be greater than anticipated, the proponent should:

- assess the significance of these impacts;
- investigate measures to minimise these impacts; and
- describe what measures would be implemented to reduce, minimise, mitigate or remediate these impacts in the future to the satisfaction of the RMS, and, if required, NOW and / or Sydney Catchment Authority.

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## **DISCLAIMER**

This report was prepared in accordance with the scope of services set out in the contract between GeoTerra Pty Ltd (GeoTerra), Groundwater Exploration Services (GES) and the client, or where no contract has been finalised, the proposal agreed to by the client. To the best of our knowledge the report presented herein accurately reflects the client's intentions when it was printed. However, the application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document.

The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site / sites in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site / sites at all points. Should information become available regarding conditions at the site, GeoTerra / GES reserve the right to review the report in the context of the additional information.

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**APPENDIX A**

**DRILL HOLE and PIEZOMETER INSTALLATION**

**LOGS**

Coordinates: E 303149  
 Datum:

N 6196144  
 Elevation: 0

Depth	Symbol	Lithology	Construction	Other
0		Ground Surface		
		<b>Sandstone</b> orange bm		100mm diameter hole
		<b>Sandstone</b> grey yellow		
2				
		<b>Sandstone</b> brown yellow		
4		<b>Sandstone</b> orange brown		
		<b>Sandstone</b> brown yellow		open hole SWL
6		<b>Sandstone</b> light brown		
8		<b>Sandstone</b> light brown / yellow		joint inflow zone
10				
12		<b>Sandstone</b> yellow brown		sealed hole SWL slightly moist inflow
14				joint inflow zone
				TD 15.04

Driller:

Drilling Method: Dry hammer

Drilling Equipment:

Drilling Start: 03/05/2016

Drilling Finish: 03/05/2016

# NON-CORE DRILL HOLE - GEOLOGICAL LOG

HOLE NO : BH-G1

PROJECT : M1 IMPROVEMENTS - STAGE 1 PICTON ROAD TO BELLAMI CREEK  
LOCATION : MT OUSLEY - BROKERS NOSE FIRE TRAIL

FILE / JOB NO : SG0017  
SHEET : 1 OF 3

POSITION : E: 303107.000, N: 6196214.000 (56 MGA94) SURFACE ELEVATION : ANGLE FROM HORIZONTAL : 90°  
RIG TYPE : GEOPROBE MOUNTING : Track CONTRACTOR : TERRATEST DRILLER : L ROBERTS  
DATE STARTED : 4/5/16 DATE COMPLETED : 4/5/16 DATE LOGGED : 4/5/16 LOGGED BY : DH CHECKED BY :

DRILLING					MATERIAL						
PROGRESS		DRILLING PENETRATION	GROUND WATER LEVELS	SAMPLES & FIELD TESTS	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	MATERIAL DESCRIPTION Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	STRUCTURE & Other Observations
DRILLING & CASING	WATER										
<div>ADT</div> <div>CASING</div>	N/A	VE			0.0		SM	0.15m SILTY SAND: pale yellow, medium to coarse grained sand, with fine to medium gravel, gravel is mixed fill material - recycled asphalt and sandstone SANDSTONE: pale yellow, medium grained; highly weathered, medium strength	M	D	FILL
		F									
		H									
					1.0			Continued as Cored Drill Hole			
					2.0						
					3.0						
					4.0						
					5.0						
					6.0						
					7.0						
					8.0						

See Explanatory Notes for details of abbreviations & basis of descriptions.

ROADS AND MARITIME SERVICES, NSW

# CORED DRILL HOLE LOG

HOLE NO : BH-G1

FILE / JOB NO : SG0017

SHEET : 2 OF 3

PROJECT : M1 IMPROVEMENTS - STAGE 1 PICTON ROAD TO BELLAMI CREEK  
LOCATION : MT OUSLEY - BROKERS NOSE FIRE TRAIL

POSITION : E: 303107.000, N: 6196214.000 (56 MGA94)

SURFACE ELEVATION :

ANGLE FROM HORIZONTAL : 90°

RIG TYPE : GEOPROBE

MOUNTING : Track

CONTRACTOR : TERRATEST

DRILLER : L ROBERTS

DATE STARTED : 4/5/16

DATE COMPLETED : 4/5/16

DATE LOGGED : 4/5/16

LOGGED BY : DH

CHECKED BY :

CASING DIAMETER : 90 mm

BARREL (Length) : 3.30 m

BIT : STEPPED FACE

BIT CONDITION : GOOD

DRILLING				MATERIAL				FRACTURES			
PROGRESS	LOSS	SAMPLES & FIELD TESTS	DEPTH (m)	GRAPHIC LOG	DESCRIPTION	Weathering	ESTIMATED STRENGTH (s(50))	NATURAL FRACTURE (mm)	VISUAL	ADDITIONAL DATA	
DRILLING & CASING	WATER	CORE LOSS (DRILL RUN %)			ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable)		EL -0.03 VL -0.1 L -0.3 M -1 H -3 VH -10 EH	20 40 100 300 1000		(joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other	
			0.0								
		48% LOSS	1.0		0.90m START CORING AT 0.90m						
			1.20m		CORE LOSS 0.30m (0.90-1.20)						
			1.75m		SANDSTONE: pale yellow, medium to coarse grained, layered, indistinctly bedded at 0° - 5°, quartzose, with fine quartz gravel	SW					
			2.0		CORE LOSS 0.28m (1.75-2.03)					SM 0° Clay PR RF thickness unknown	
		32% LOSS	2.03m		SANDSTONE: as above	SW				SM 0° Clay PR RF thickness unknown DB DB BP 5° Clay PR RF	
			2.61m		CORE LOSS 0.65m (2.61-3.26)						
			3.0		CORE LOSS 0.65m (2.61-3.26)						
			3.26m		SANDSTONE: as above	MW / SW				JT 10° CN PR RF	
			4.0		fossil or imprint from piece of gravel at 3.76m					SM 0° Clay PR 30 mm BP 5° Clay UN RF	
			4.10m		CORE LOSS 0.10m (4.00-4.10)					HB	
			4.10m		SANDSTONE: as above	MW / SW				HB	
			5.0		CORE LOSS 0.30m (5.00-5.30)					HB	
			5.30m		SANDSTONE: as above					DB	
		17% LOSS	5.40m		CORE LOSS 0.10m (5.40-5.50)					SM 5° Clay PR RF 10 mm	
			5.50m		SANDSTONE: as above	MW / SW				HB	
			6.0							DB	
		0% LOSS	6.00							DB	
			6.50							DB	
		0% LOSS	6.50							DBs	
			6.60m		SANDSTONE: as above becoming distinctly cross bedded at 0° - 90° with orange brown iron staining	SW				SM 0° Clay PR RF 10 mm	
			7.0							HB	
			7.50			EW				SM 5° Clay PR 90 mm	
		0% LOSS	7.50			SW				DB	
			8.0							HB	

See Explanatory Notes for details of abbreviations & basis of descriptions.

ROADS AND MARITIME SERVICES, NSW

# CORED DRILL HOLE LOG

HOLE NO : BH-G1

FILE / JOB NO : SG0017

SHEET : 3 OF 3

PROJECT : M1 IMPROVEMENTS - STAGE 1 PICTON ROAD TO BELLAMI CREEK  
LOCATION : MT OUSLEY - BROKERS NOSE FIRE TRAIL

POSITION : E: 303107.000, N: 6196214.000 (56 MGA94) SURFACE ELEVATION : ANGLE FROM HORIZONTAL : 90°

RIG TYPE : GEOPROBE MOUNTING : Track CONTRACTOR : TERRATEST DRILLER : L ROBERTS

DATE STARTED : 4/5/16 DATE COMPLETED : 4/5/16 DATE LOGGED : 4/5/16 LOGGED BY : DH CHECKED BY :

CASING DIAMETER : 90 mm BARREL (Length) : 3.30 m BIT : STEPPED FACE BIT CONDITION : GOOD

DRILLING				MATERIAL				FRACTURES			
DRILLING & CASING	WATER	CORE LOSS (% LOSS)	SAMPLES & FIELD TESTS	DEPTH (m)	GRAPHIC LOG	DESCRIPTION ROCK TYPE : Colour, Grain size, Structure (texture, fabric, mineral composition, hardness alteration, cementation, etc as applicable)	Weathering	ESTIMATED STRENGTH (s(50)) ● Axial ○ Diametral	NATURAL FRACTURE (mm)	VISUAL	ADDITIONAL DATA (joints, partings, seams, zones, etc) Description, orientation, infilling or coating, shape, roughness, thickness, other
		0% LOSS		8.0		SANDSTONE: as above	SW				
				9.0							
				10.0							
				10.51							
				11.0		BOREHOLE BH-G1 TERMINATED AT 10.51 m					
				12.0							
				13.0							
				14.0							
				15.0							
				16.0							

See Explanatory Notes for details of abbreviations & basis of descriptions.

ROADS AND MARITIME SERVICES, NSW







PointID : BH-G1 Depth Range: 0.00 - 5.00 m



PointID : BH-G1 Depth Range: 5.00 - 10.00 m



**Transport**  
Roads & Maritime  
Services

**M1 IMPROVEMENTS - STAGE 1 PICTON  
ROAD TO BELLAMI CREEK  
Core Photo - BH-G1**

DRAWN	GD	DATE	11/05/2016
CHECKED	DH	DATE	11/05/2016
SCALE	Not To Scale		A4
PROJECT No	SG0017	FIGURE No	1/2





PointID : BH-G1 Depth Range: 10.00 - 10.51 m

# Appendix J

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Greenhouse gas assessment

## Materiality Checklist

Note:

- 'Item' relates directly to Carbon Gauge GHG emission calculator input fields
- Bold text in 'Assumption' column indicates item needs addressing and further information required.
- Please include relevant responses in 'Response' column

### Construction

Item	Assumption	Response
Will a diesel generator will be used to provide to the project site office for more than 12 months	Yes	Suggest Yes as power cannot be guaranteed to site.
Will more than 120 buildings be required to be demolished per 1km of road?	No	Agreed
Will more than 0.5ha of vegetation be removed?	Yes	Agreed
Will project involve tunnelling?	No	Agreed
Is the project located more than 50km from nearest material suppliers/quarry/city?	Yes, assumed for aggregate, cement and steel materials.	Depends on the reasoning behind the query. For example all fill will not be sourced from a location >50km from site as it will largely be from site. If for some select / AC layers then appropriate.
Will the project utilise on-site batching plants or continuously operating stationary plant and equipment for more than 6 months?	No	Agreed
Will the project include road safety barriers along more than 50% of the road if barriers are used on both sides of a dual carriageway (ie. 4 sets) or 100% of road length if used on both sides of a single carriageway?	Assumed yes	Assume yes.
Will the project include noise walls along more than 50% of the road length on both sides or 100% of road length on one side?	Assumed no	Agreed

Operation		
Will project include street lighting continuously along more than 20% of the road length?	Will be installed but not triggering inclusion. Assumed no.	No, no street lighting proposed
Will project included traffic signals and/or interchanges using incandescent lights that are less than 11.5km apart?	No	Agreed
Will project include traffic signals and/or interchanges using quartz halogen that are less than 4.5km apart?	No	Agreed
Will project included traffic signals and/or interchanges using LED that are less than 2.0km apart?	No	Agreed
Will the project include emissions from vehicles using the road during its 50 year life?	Yes – please provide more information/TRAQ outputs required	Noted.

## Inputs List

Item	Assumption	Response
Estimated value (\$m)	\$84M (\$42 State, \$42 Federal)	Agreed
Project Duration (months)	24 months	Agreed

## Construction

Item	Assumption	Response
Fuel Type	Assumed all site vehicles running on diesel with 50% site vehicles using petrol, as this gives a more conservative total than if all site vehicles were running on diesel.	Agreed
Pavement Type	Full depth 74,000 m <sup>2</sup> Overlay 32,700 m <sup>2</sup> Concrete berm 7,300 m <sup>2</sup>	Provided by RMS
Structures - Bridges (including overpasses)	No overpasses/bridges to be constructed	Agreed

Structures – Retaining walls	None	No retaining walls on stage 1
Drainage - Kerbing	SO drains 4,870 m	Provided by RMS
Drainage – culverts	Following assumed: <ul style="list-style-type: none"> <li>• Small &lt;450 RCP = 0.05 km</li> <li>• Medium 450-0750 RCP = 0.45 km</li> <li>• Large 750 – 1200 RCP = 0.03 km</li> </ul>	Provided by RMS
Drainage – open unlined drains	Open drains 4,000 m	Provided by RMS
Road Furniture – Road safety barriers	Assumed: <ul style="list-style-type: none"> <li>• W-beam barrier (assuming including Thrie beam) = 2.3 km</li> <li>• F-type (assuming including “Tall Wall”) = 3.4 km</li> </ul>	Provided by RMS
Road Furniture – Noise walls	No noise walls.	Agreed
Material Transport	To be conservative, the following was assumed: Material Types: <ul style="list-style-type: none"> <li>• Aggregate (assumed heavy goods vehicle transport of 60km for pavements)</li> <li>• Asphalt and Bitumen (assumed heavy goods vehicle transport of 60km for pavements)</li> <li>• Cement and concrete (assumed heavy goods vehicle transport of 60km for drainage)</li> <li>• Steel (assumed heavy goods vehicle transport of 60km for road furniture)</li> <li>• Timber (none)</li> </ul>	Good summary, agreed
Earthworks	Assumed: <ul style="list-style-type: none"> <li>• Cut 335,000 m<sup>3</sup></li> <li>• Fill 356,000 m<sup>3</sup></li> <li>• Topsoil 20,000 m<sup>3</sup> (Assumed nominal 0.1 m topsoil depth over project footprint)</li> </ul>	Provided by RMS
Vegetation Removal	Calculated from Biodiversity calculations at approx.	Agreed

## Operations

Item	Assumption	Response
Street lighting	No	No, no lighting proposed
Traffic Signals	Assumed none.	Nil signals proposed
Vehicle Use	Please advise on projected emissions totals from vehicles	Calculated through TRAQ – based 2038 traffic volumes (worst case)



## Summary Report

**Note:** This Workbook is designed to enable a consistent methodology for the assessment of significant emission sources and estimation of greenhouse gas emissions. As such it deliberately does not cover activities and emission sources assessed as insignificant, and it is not designed for compliance reporting.

### Project Description

Project title	Mount Ousley Mount Ousley Motorway Improv
Project location	Mount Ousley
State	NSW
Description	The upgrade of M1 Princes Motorway at Mount Ousley would be built in two stages. Stage 1 (southern section) extends between the Picton Road interchange and Bellambi Creek, Mount Ousley. Stage 2 (northern section) extends between Bellambi Creek and Bulli Pass at
Project Value (\$m)	42
Project Duration (Months)	24

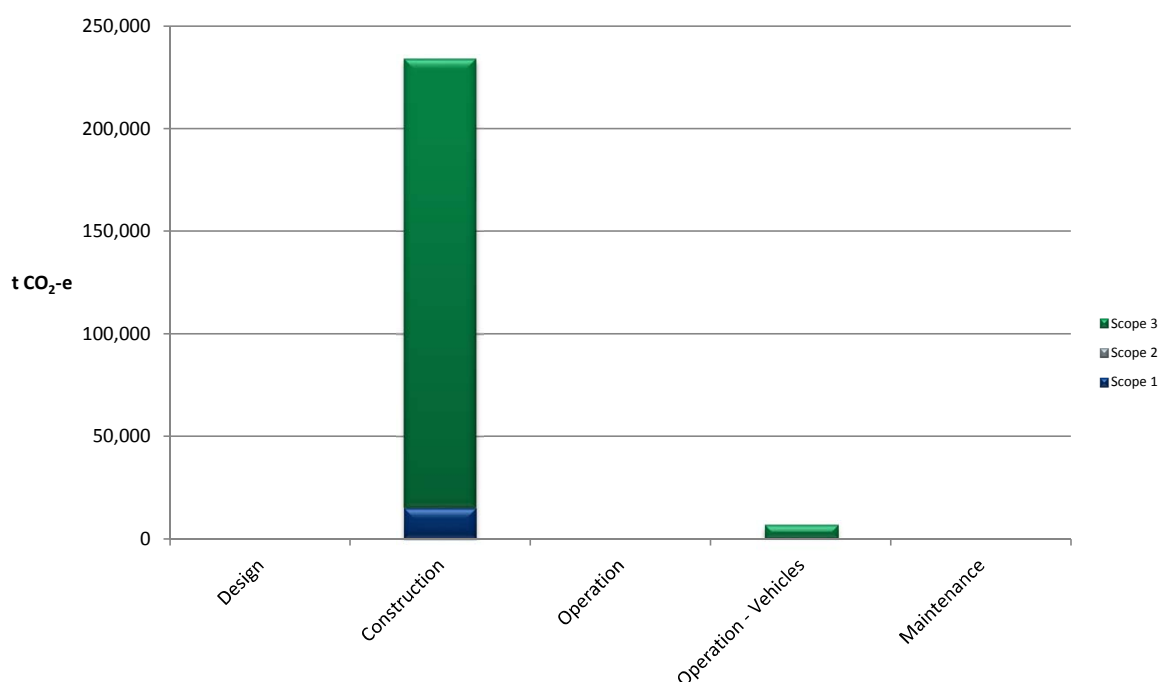
### Greenhouse Gas Emissions

<b>Scope 1 emissions</b>	Emissions released into the atmosphere as a direct result of an activity, or series of activities (including ancillary activities) that constitutes the facility.
<b>Scope 2 emissions</b>	Emissions released as a result of one or more activities that generate electricity, heating, cooling or steam that is consumed by the facility but that do not form part of the facility.
<b>Scope 3 emissions</b>	Emissions that occur outside the site boundary of a facility as a result of activities at a facility that are not Scope 2 emissions.

### Project Summary

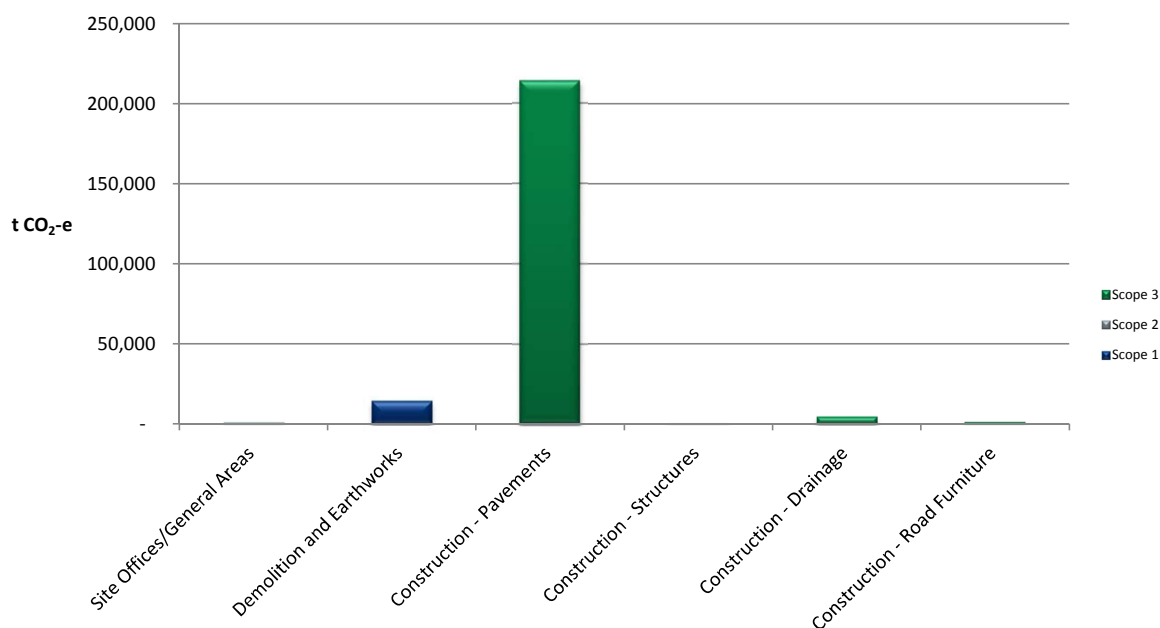
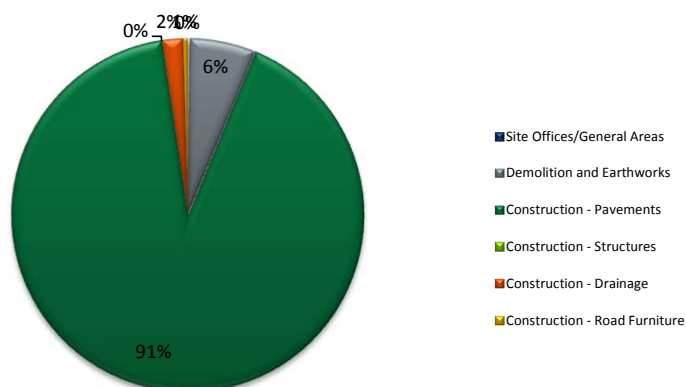
Major Activity	Scope 1	Scope 2	Scope 3	Total
Design	0	0	0	0
Construction	15,021	0	219,004	234,024
Operation	0	0	0	0
Operation - Vehicles	0	0	6,487	6,487
Maintenance	0	0	0	0
<b>Total</b>	<b>15,021</b>	<b>0</b>	<b>225,491</b>	<b>240,511</b>

**GHGe Summary by Activity**



**Construction Summary****GHGe Summary by activity**

	Scope 1	Scope 2	Scope 3	Total
Site Offices/General Areas	461	0	35	496
Demolition and Earthworks	13,957	0	97	14,054
Construction - Pavements	509	0	213,453	213,962
Construction - Structures	0	0	0	0
Construction - Drainage	81	0	4,377	4,458
Construction - Road Furniture	13	0	1,042	1,055
<b>Total</b>	<b>15,021</b>	<b>0</b>	<b>219,004</b>	<b>234,024</b>

**GHGe Summary by Activity****GHGe Summary by Activity****Operations Summary (Emissions are calculated for a 50 year period)**

Summary	Scope 1	Scope 2	Scope 3	Total
Lighting	-	-	-	-

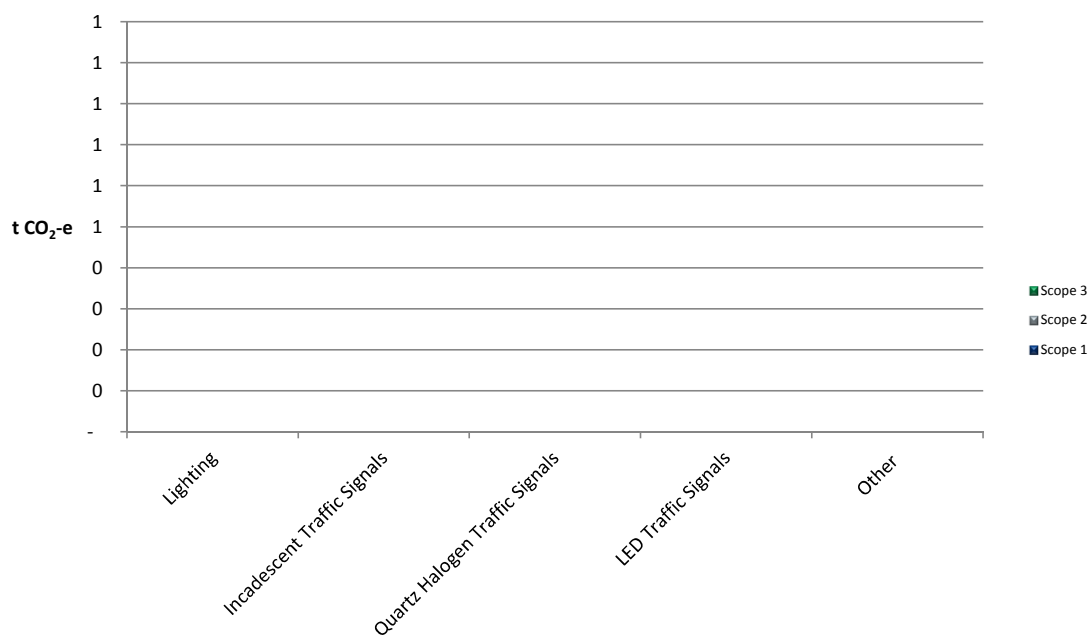


Incandescent Traffic Signals	-	-	-	-
Quartz Halogen Traffic Signals	-	-	-	-
LED Traffic Signals	-	-	-	-
Other	-	-	-	-
<b>Total</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>

**Summary - Vehicles**

Vehicle Use

	Scope 1	Scope 2	Scope 3	Total
	-	-	6,487	6,487
<b>Total</b>	<b>-</b>	<b>-</b>	<b>6,487</b>	<b>6,487</b>

**Operations GHGe Summary**

# Appendix K

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Noise and vibration assessment

Project name	Mt Ousley
Scenario name	Earthworks
Receiver address	Bull
Select area ground type	Rural
Select type of background noise level input	Representative Noise Environment

Is all plant at the same representative distance to the receiver? Y/N	Y	All at Representative Distance
Representative distance (m)	1200	

<b>Total SPL L Aeq(15minute)(dB(A))</b>	<b>37</b>
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		Residential receiver	Non-residential receivers						
			Classroom at schools and other educational institutions	Hospital wards and operating theatres	Place of worship	Active recreation	Passive recreation	Industrial premise	Offices, retail outlets
Noise Management Level (dB(A))	Standard hours	50	55	65	55	65	60	75	70
	Day (OOHW)	45	55	65	55	65	60	75	70
	OOHW Period 1	40		65	55	65	60	75	70
	OOHW Period 2	35		65	55			75	70
Level above background (dB(A))	Standard hours								
	Day (OOHW)								
	OOHW Period 1	2							
	OOHW Period 2	7							
Level above NML (dB(A))	Standard hours								
	Day (OOHW)								
	OOHW Period 1								
	OOHW Period 2	2							
Additional mitigation measures	Standard Hours	-	-	-	-	-	-	-	-
	Day (OOHW)	-	-	-	-	-	-	-	-
	OOHW Period 1	-	-	-	-	-	-	-	-
	OOHW Period 2	N	-	-	-	-	-	-	-

Abbreviation	Measure
N	Notification (letterbox drop or equivalent)
SN	Specific notifications
PC	Phone calls
IB	Individual briefings
RO	Respite offer
R1	Respite period 1
R2	Respite period 2
DR	Duration respite
AA	Alternative accommodation
V	Verification

1. Enter project name (cell C9).
2. Enter scenario name (cell C10).
3. Enter receiver address (cell C11).
4. Select area ground type (cell C12) - hard ground (for a conservative assessment or across the river/valley), urban or rural.
5. Select the type of background noise level input - Representative noise environment (to make assumptions) or user input (where noise monitoring data is available).
6. Is all plant at the same representative distance to the receiver? Select Y or N (cell C24):
  - (a) where Y is selected - enter the representative distance in cell C25.
  - (b) where N is selected - go to step #7
7. For the scenario (e.g. shallow excavation), select plant from the drop-down list in cells A28 to A47 (e.g. dump trucks + excavator).
  - (a) enter quantity for each selected plant in cells D28 to D47.
  - (b) where N is selected from step #6 - enter the distance to receiver for each individual plant in cells E28 to E47.
  - (c) is there line of sight to receiver? select from drop down list in cells F28 to F47.
8. Identify the level above background and/or noise management level (see rows 57 to 62).
9. Identify and implement standard mitigation measures where feasible and reasonable. Include any shielding implemented as part of the standard mitigation measures by changing the selection in the Is there line of sight to receiver drop-down list.
10. Identify and implement feasible and reasonable additional mitigation measures (see rows 63 to 65).
11. Document a summary report detailing:
  - (a) context description (including location, duration, hours of work, construction methodology, plant, potentially impacted receivers, etc.).
  - (b) background noise levels.
  - (c) noise management levels.
  - (d) predicted noise levels for each time period.
  - (e) sleep disturbance affected distance for night works.
  - (f) mitigation measures.
  - (g) team member responsible for implementing mitigation measures and managing noise and vibration.



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Customer feedback  
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